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DeNap et al.

(10) **Patent No.: US 6,490,273 B1**
(45) **Date of Patent: Dec. 3, 2002**

(54) **ASYNCHRONOUS TRANSFER MODE ARCHITECTURE MIGRATION**

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(73) Assignee: **Sprint Communications Company L.P.**, Overland Park, KS (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/129,249**

(22) Filed: **Aug. 5, 1998**

(51) **Int. Cl.**[7] **H04L 12/66**; H04L 12/28

(52) **U.S. Cl.** **370/352**; 370/395.1; 370/409

(58) **Field of Search** 370/352, 353, 370/354, 355, 356, 395.7, 395.51, 395.52, 395.53, 395.6, 400, 401, 396, 395.5, 395.54, 409

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Primary Examiner—Chau Nguyen
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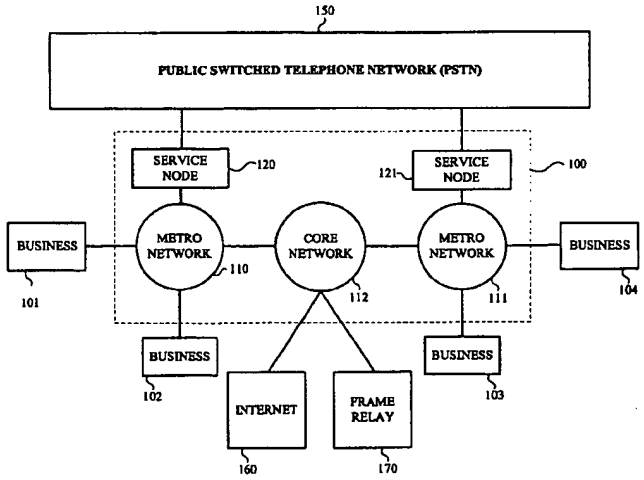
(57) **ABSTRACT**

The invention comprises a series of architectures that are implemented in four phases to provide a migration path from an initial ATM service offering to a full service ATM network. The initial ATM network includes several metropolitan ATM networks that are interconnected by a core ATM network. Each metropolitan ATM network includes a service node that controls ATM network elements to deliver services. In Phase I, a business hub that is connected to the metropolitan ATM network integrates voice, data, and Internet traffic over a single ATM connection that contains permanent Virtual Connections (PVCs) to various destinations, such as other business hubs, a gateway to local and long distance networks, the Internet, a frame relay network. In Phase II, the architecture is extended to smaller business markets. Businesses are provided with the PVC-based ATM service using xDSL/ATM connections that are multiplexed at a central office and then provided to the service node over the metropolitan ATM network. A remote dial-in feature is also added. In Phase III, a work-at-home hub is provided for telecommuting. The work-at-home hub uses an xDSL/ATM connection through the central office to the service node. Phase III also includes the deployment of a session manager and provider agents that interact to interpret user requests and establish the requisite communications paths using Switched Virtual Connections (SVCs). The business can replace existing some or all PVC-based service with more efficient SVC-based service. In Phase IV, the architecture is extended to the residential market. A residential hub is provided for residential communications over an xDSL/ATM connection through the central office to the service node. An analog hub is provided for conventional telephone service through the service node.

34 Claims, 21 Drawing Sheets



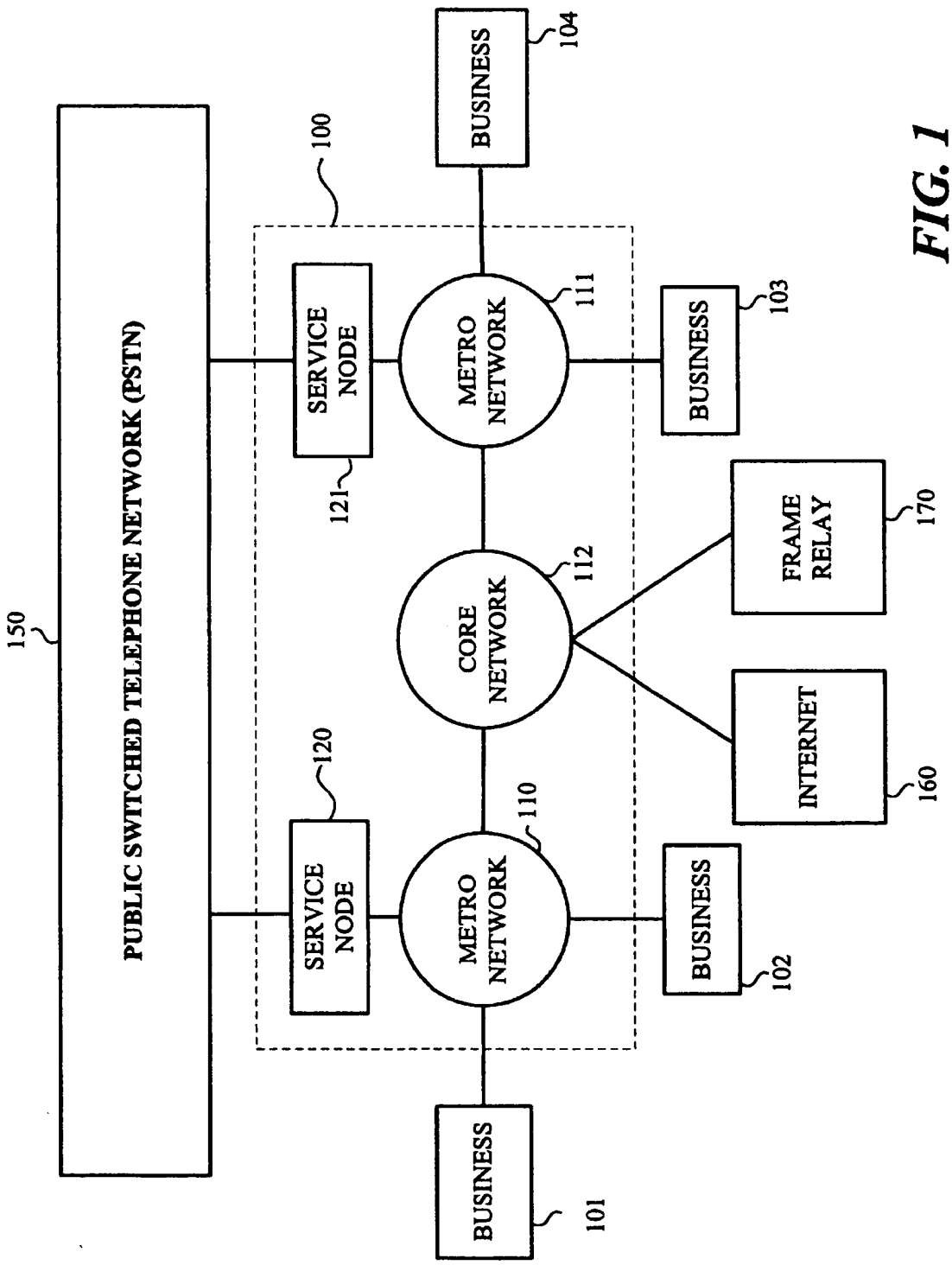

PUBLIC SWITCHED TELEPHONE NETWORK (PSTN)
150
100
SERVICE NODE
121
SERVICE NODE
120
METRO NETWORK
111
METRO NETWORK
110
CORE NETWORK
112
BUSINESS
104
BUSINESS
103
BUSINESS
102
BUSINESS
101
FRAME RELAY
170
INTERNET
160

FIG. 1

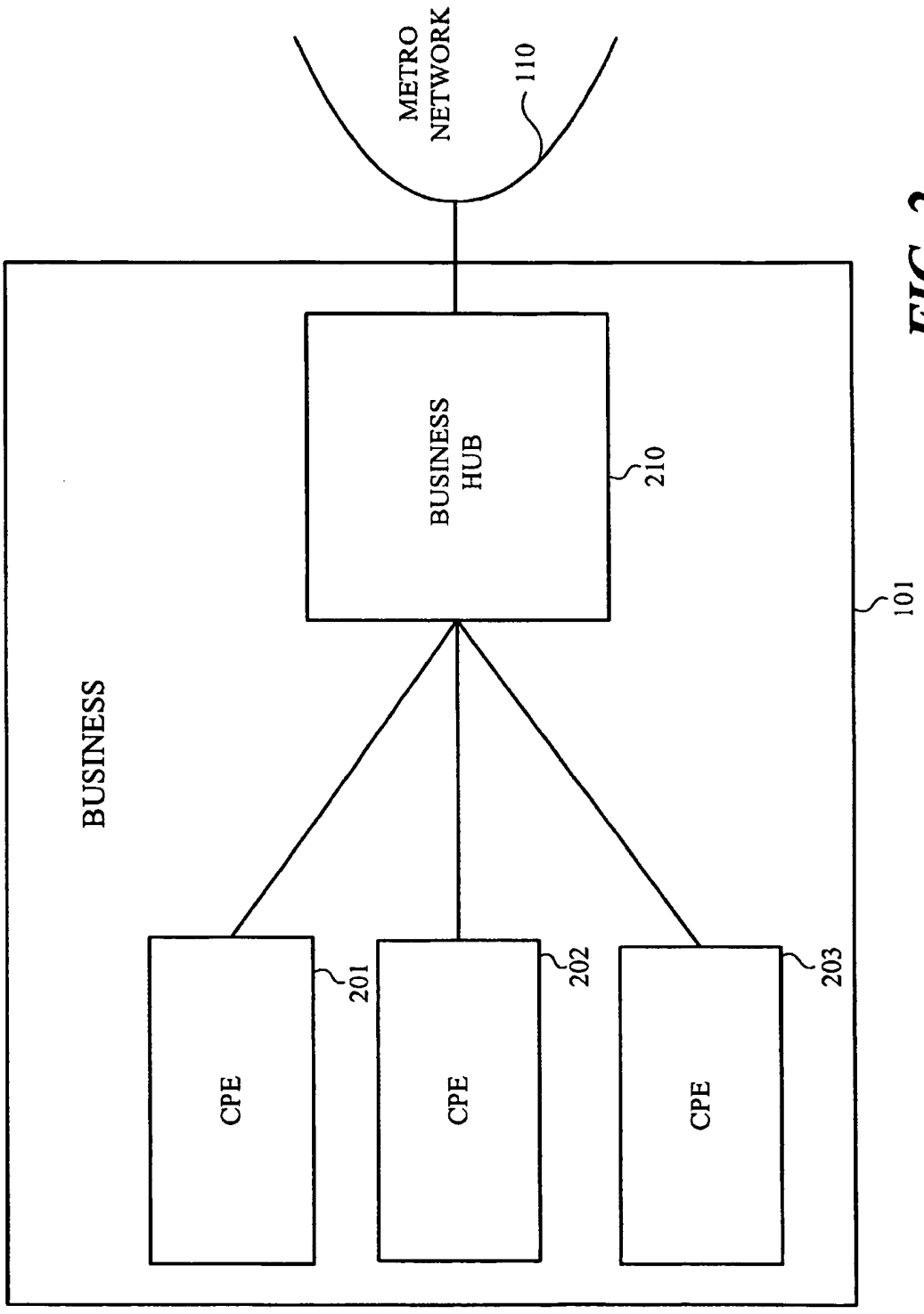
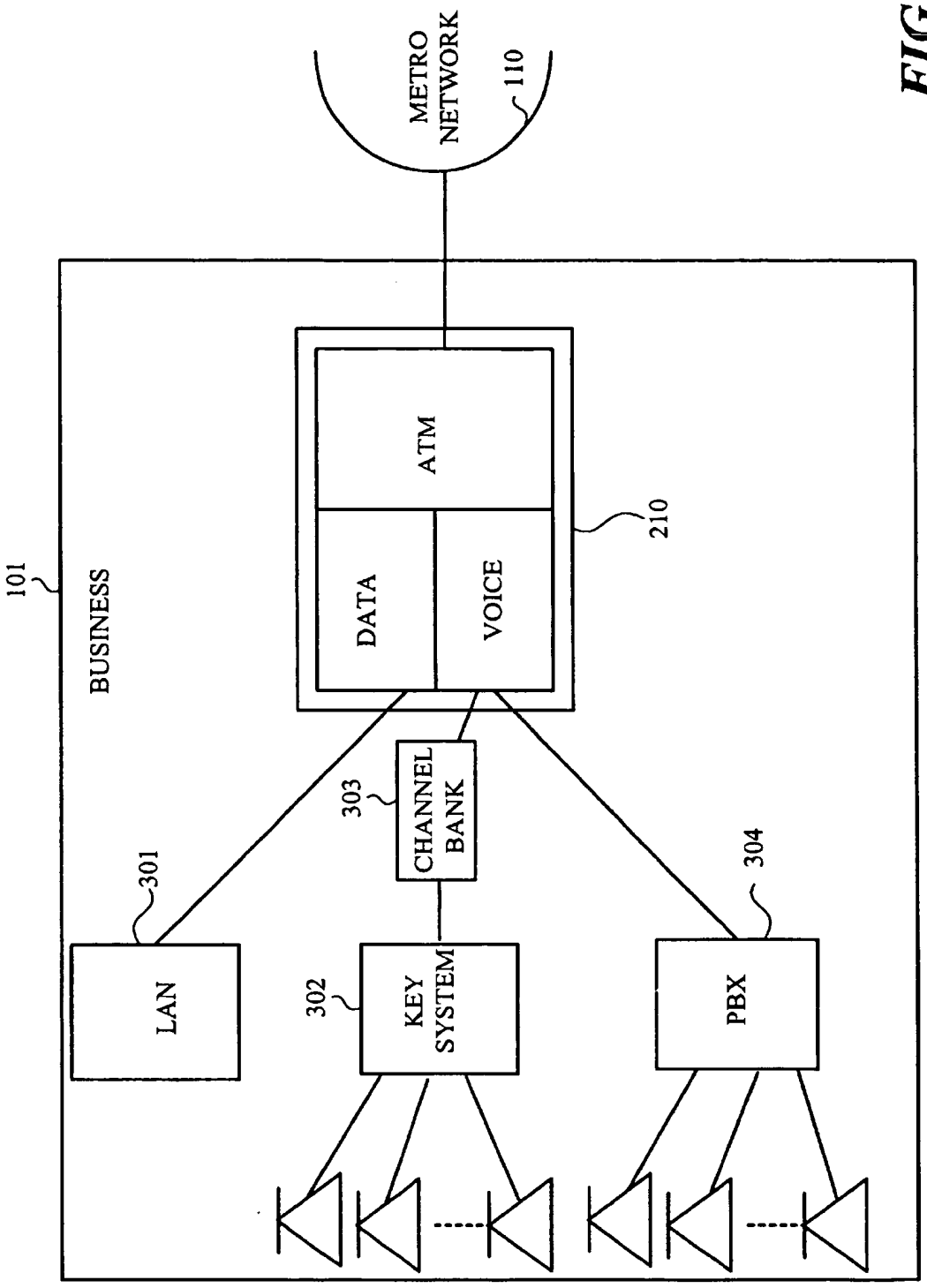

METRO NETWORK
110
BUSINESS HUB
210
BUSINESS
101
CPE
201
CPE
202
CPE
203

FIG. 2

FIG. 3


METRO NETWORK
110
ATM
DATA
VOICE
210
101
BUSINESS
303
CHANNEL BANK
301
LAN
302
KEY SYSTEM
304
PBX

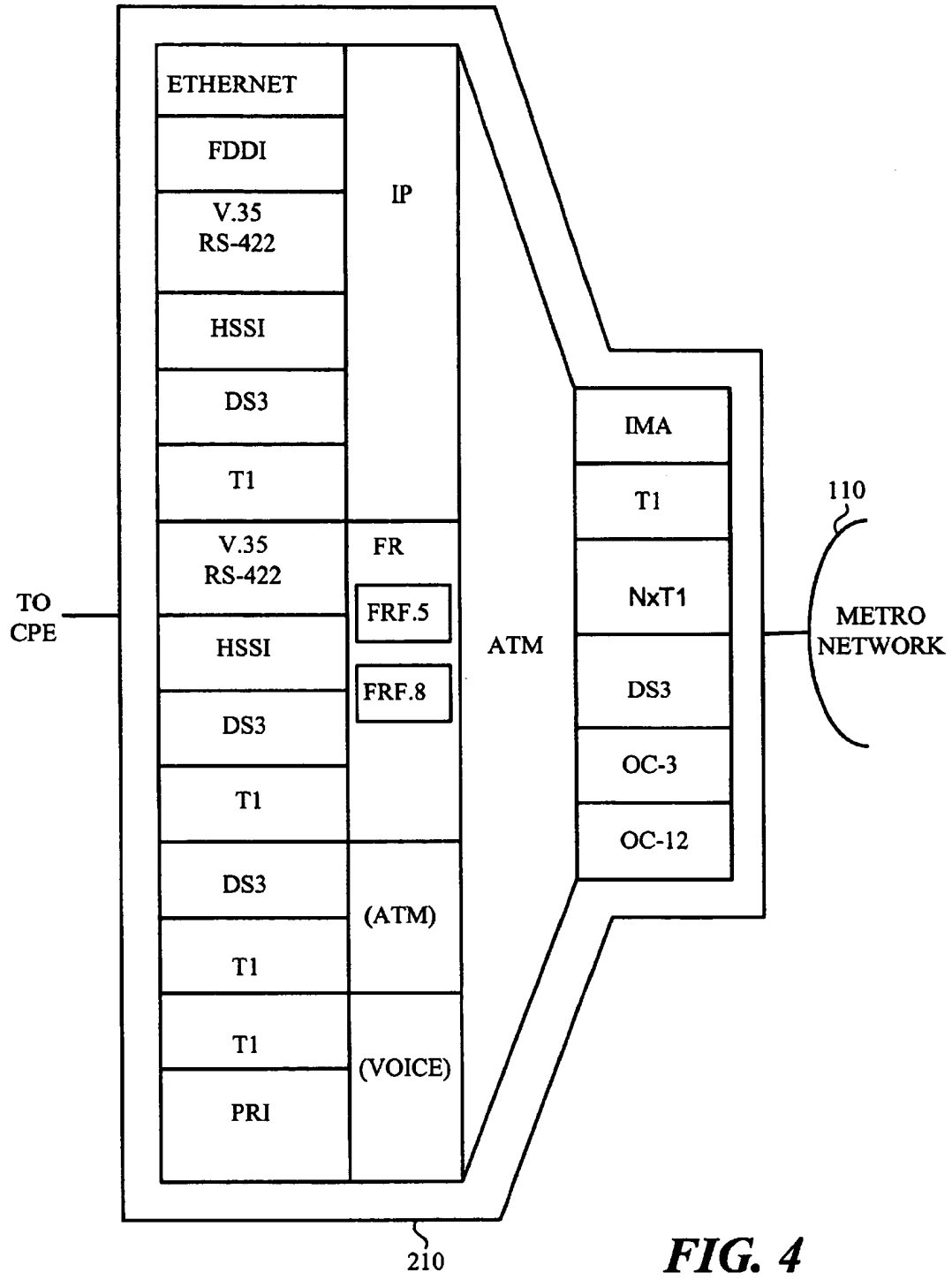

ETHERNET
FDDI
V.35
RS-422
HSSI
DS3
T1
IP
V.35
RS-422
HSSI
DS3
T1
FR
FRF.5
FRF.8
DS3
T1
(ATM)
T1
PRI
(VOICE)
TO
CPE
ATM
IMA
T1
NxT1
DS3
OC-3
OC-12
110
METRO
NETWORK
210

FIG. 4

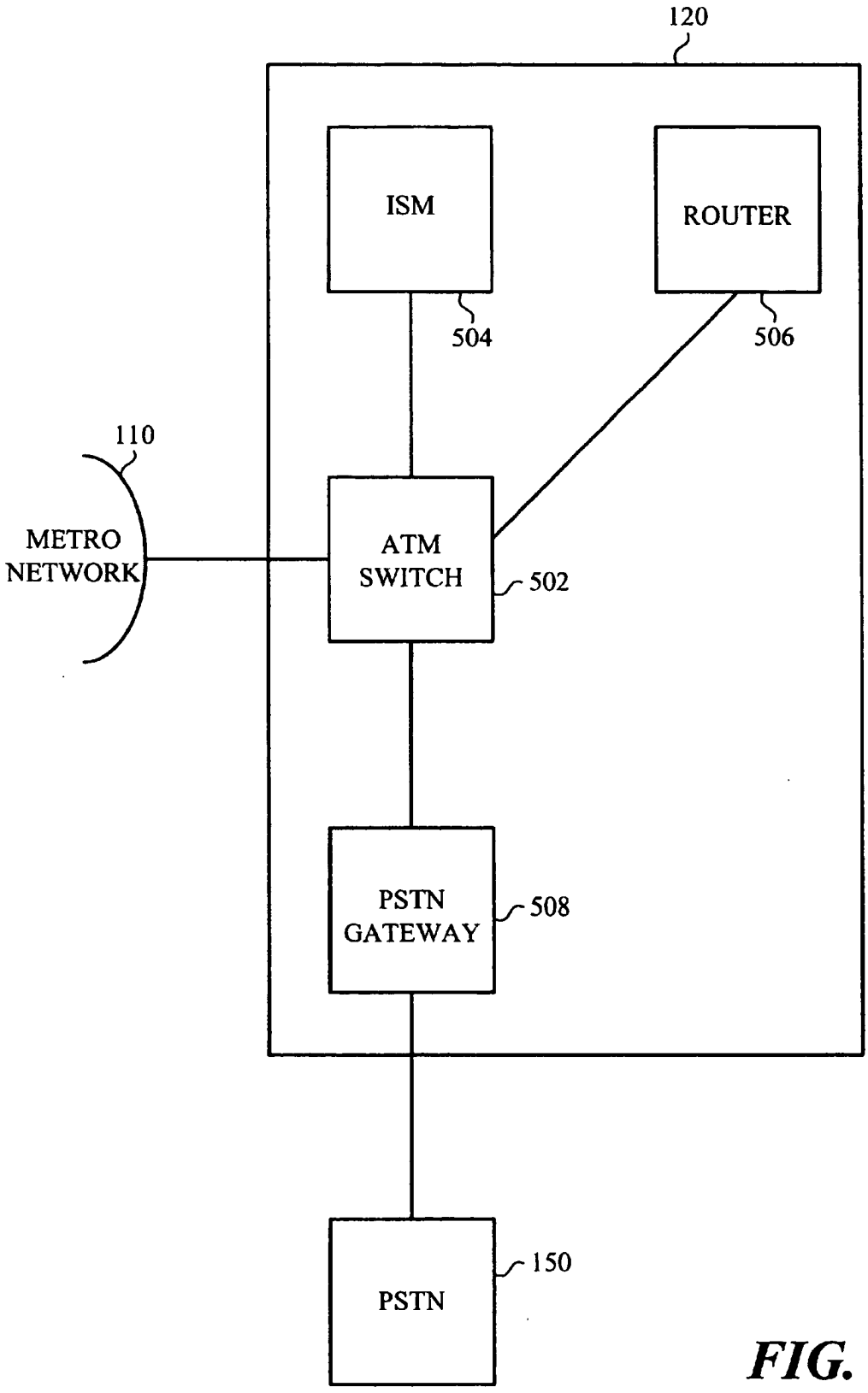

120
ISM
ROUTER
504
506
110
METRO NETWORK
ATM SWITCH
502
PSTN GATEWAY
508
PSTN
150

FIG. 5

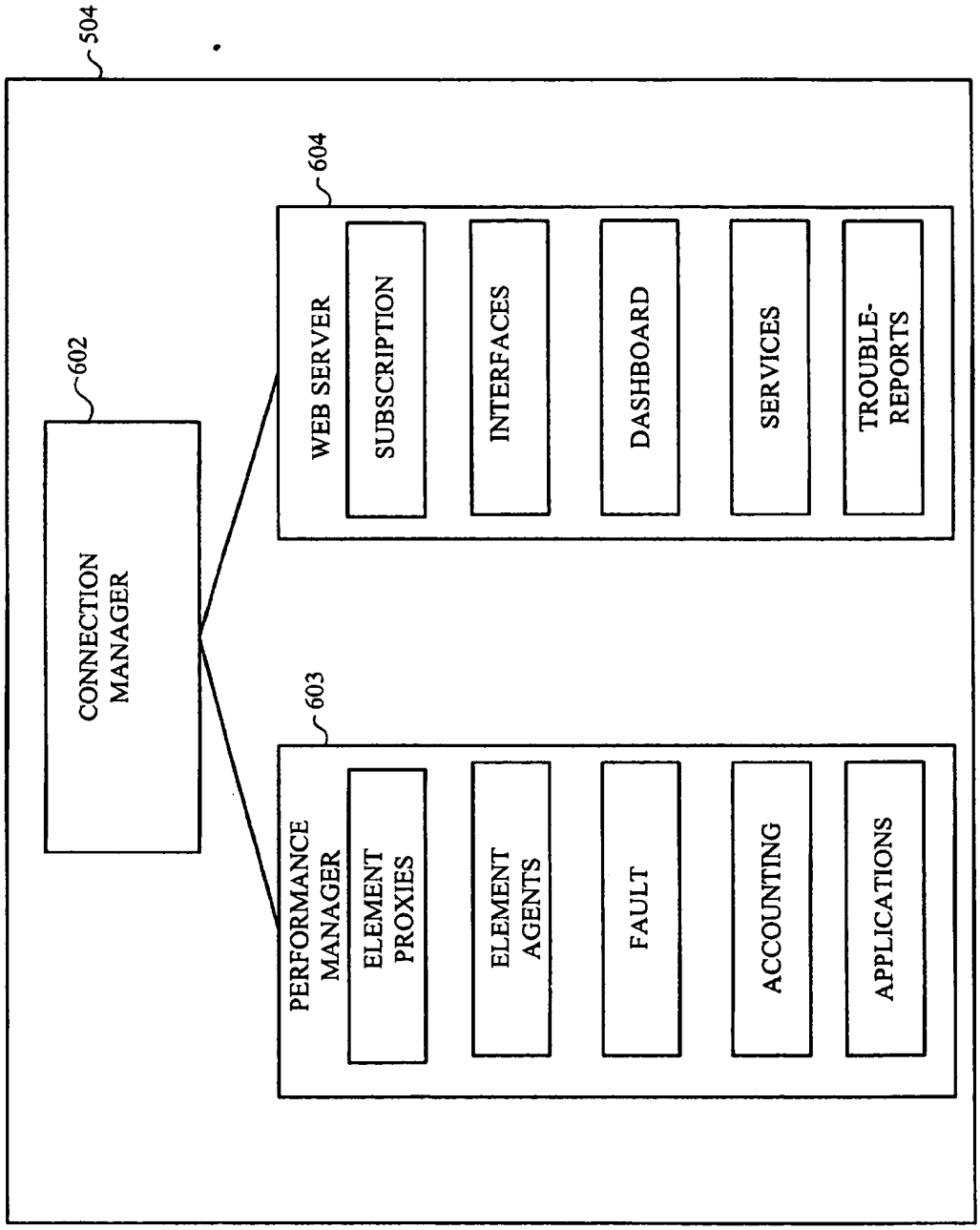

504
602
CONNECTION MANAGER
604
WEB SERVER
SUBSCRIPTION
INTERFACES
DASHBOARD
SERVICES
TROUBLE-REPORTS
603
PERFORMANCE MANAGER
ELEMENT PROXIES
ELEMENT AGENTS
FAULT
ACCOUNTING
APPLICATIONS

FIG. 6

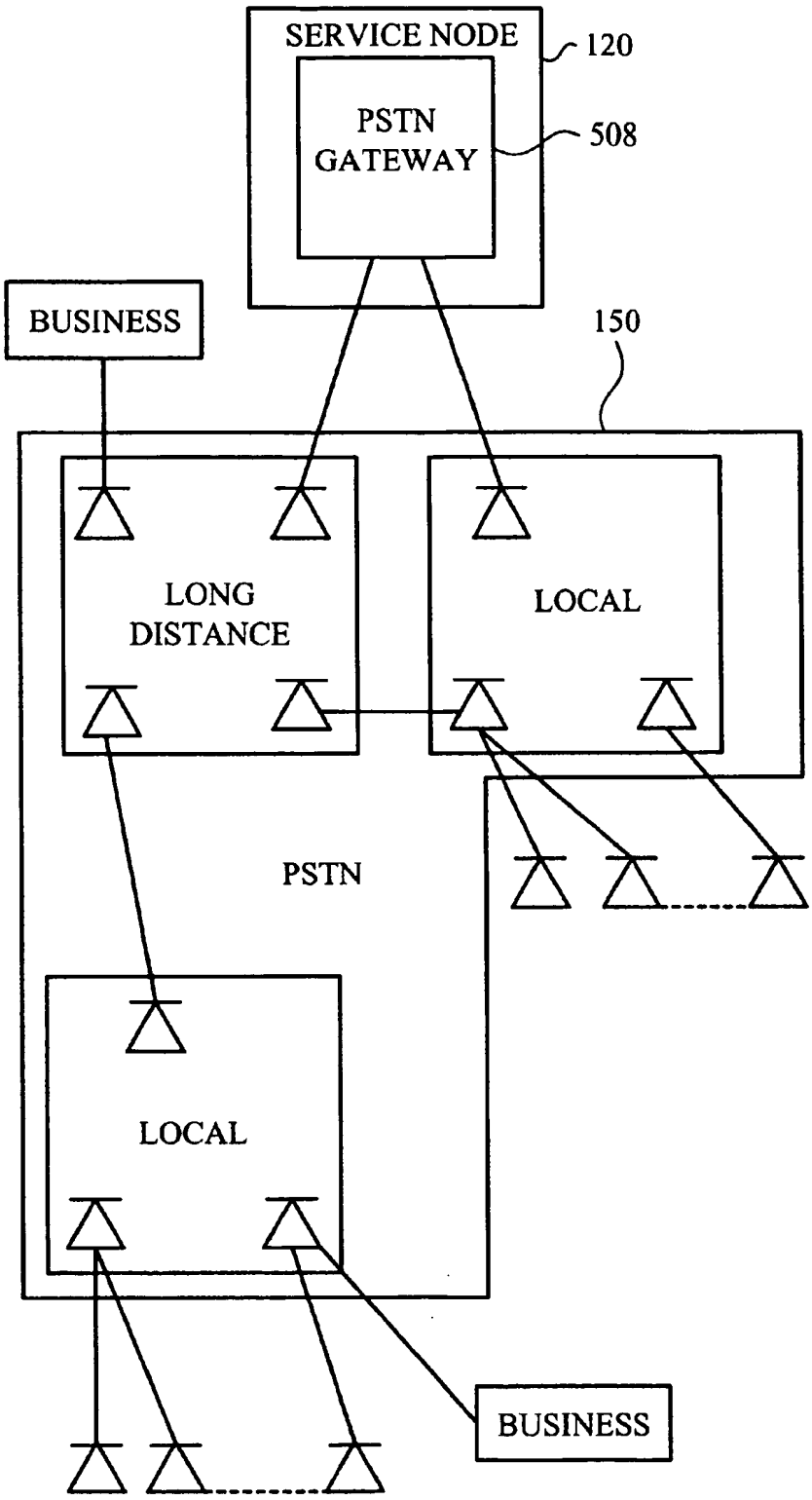

SERVICE NODE
120
PSTN
GATEWAY
508
BUSINESS
150
LONG
DISTANCE
LOCAL
PSTN
LOCAL
BUSINESS

FIG. 7

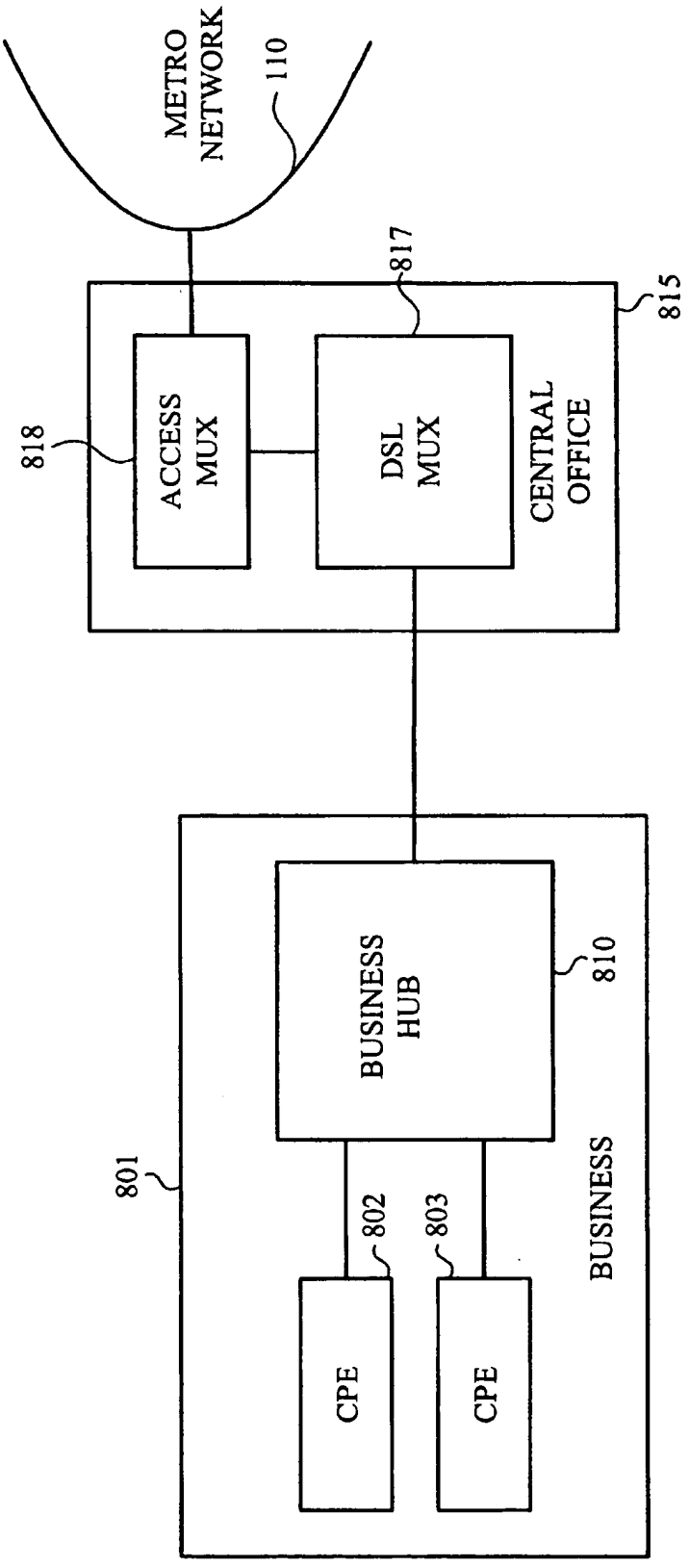

METRO NETWORK
110
817
815
818
ACCESS MUX
DSL MUX
CENTRAL OFFICE
BUSINESS HUB
810
801
802
803
CPE
CPE
BUSINESS

FIG. 8

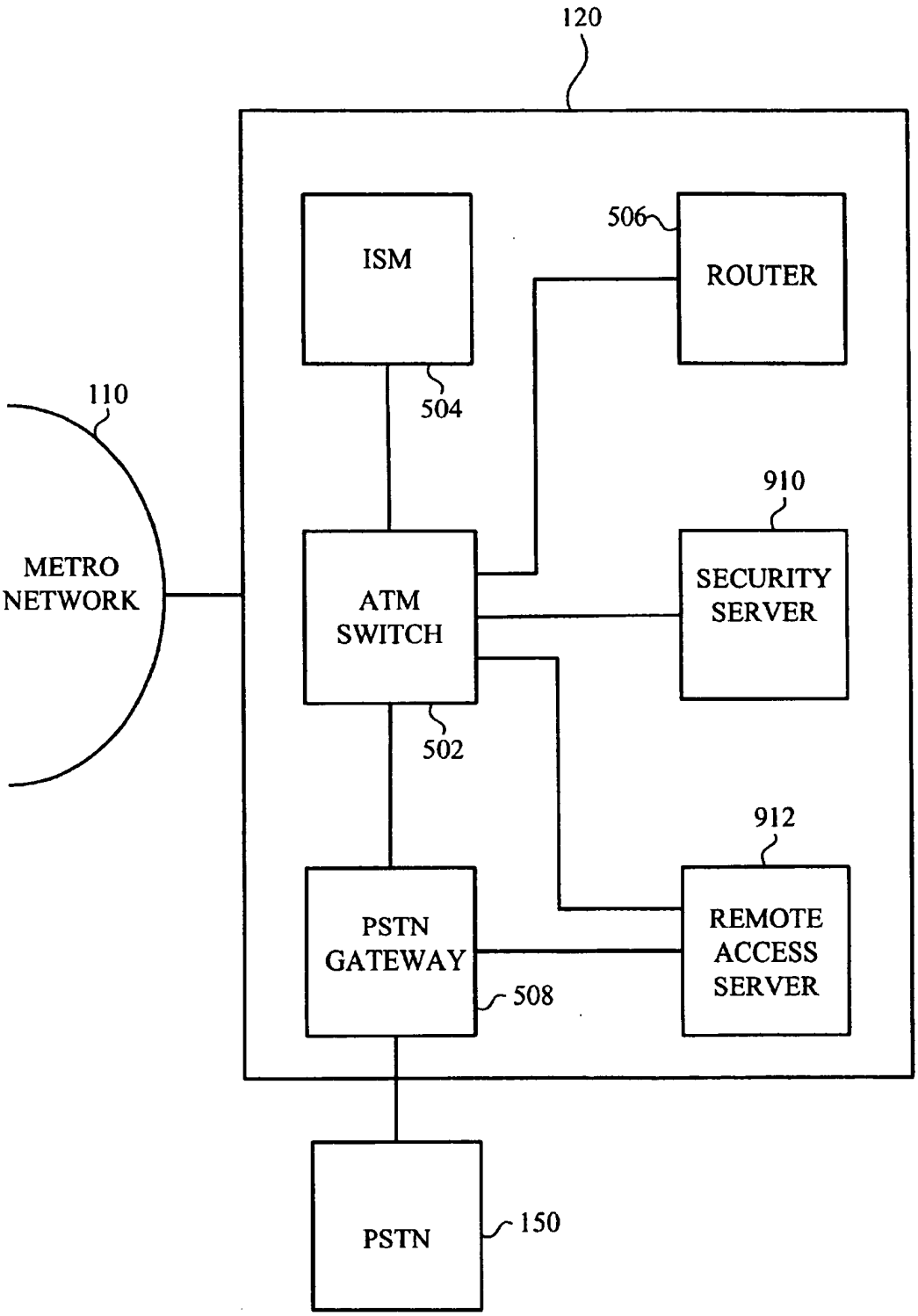

120
ISM
506
ROUTER
504
110
910
METRO NETWORK
ATM SWITCH
SECURITY SERVER
502
912
PSTN GATEWAY
REMOTE ACCESS SERVER
508
PSTN
150

FIG. 9

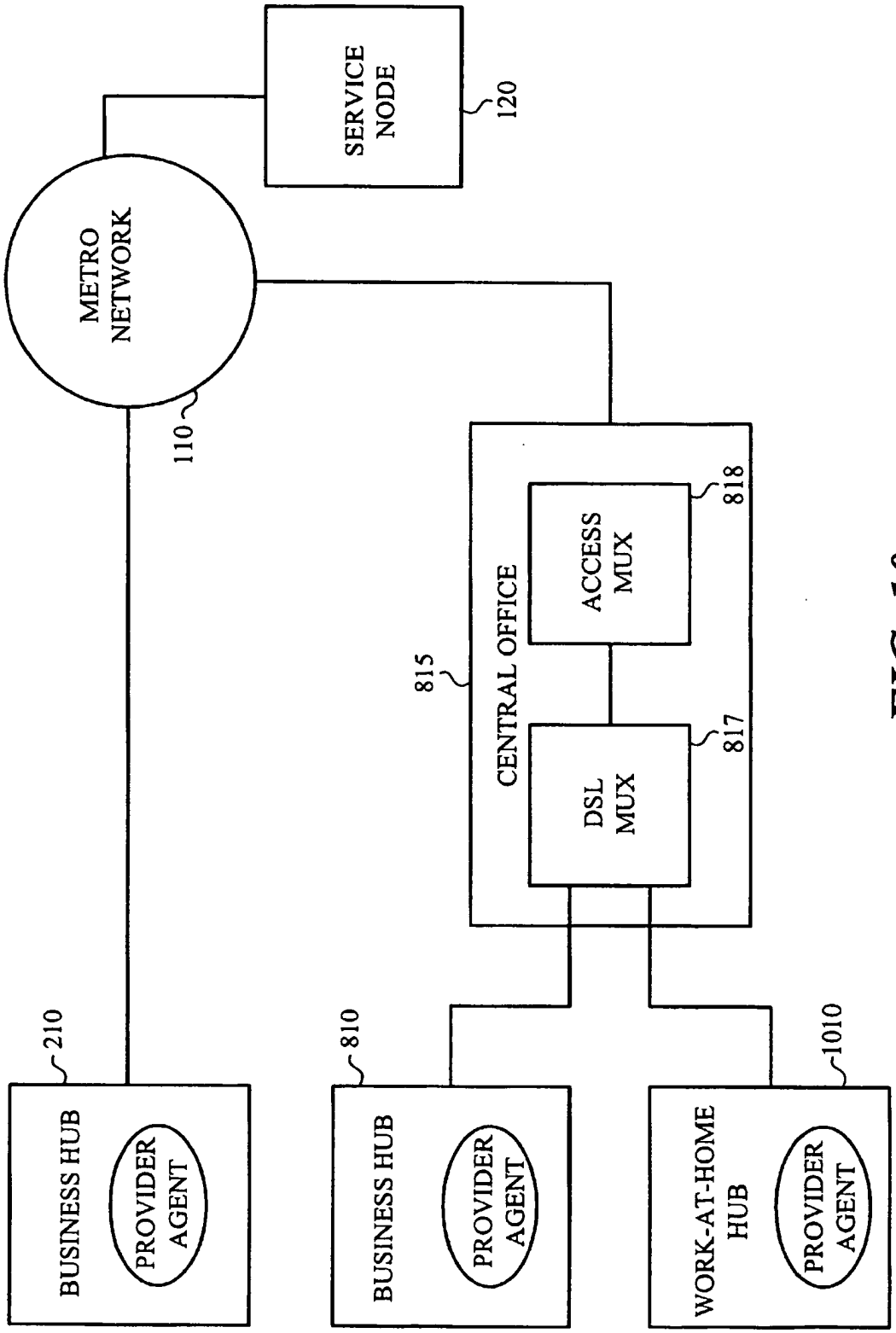

SERVICE NODE
120
METRO NETWORK
110
CENTRAL OFFICE
815
ACCESS MUX
818
DSL MUX
817
BUSINESS HUB
PROVIDER AGENT
210
BUSINESS HUB
PROVIDER AGENT
810
WORK-AT-HOME HUB
PROVIDER AGENT
1010

FIG. 10

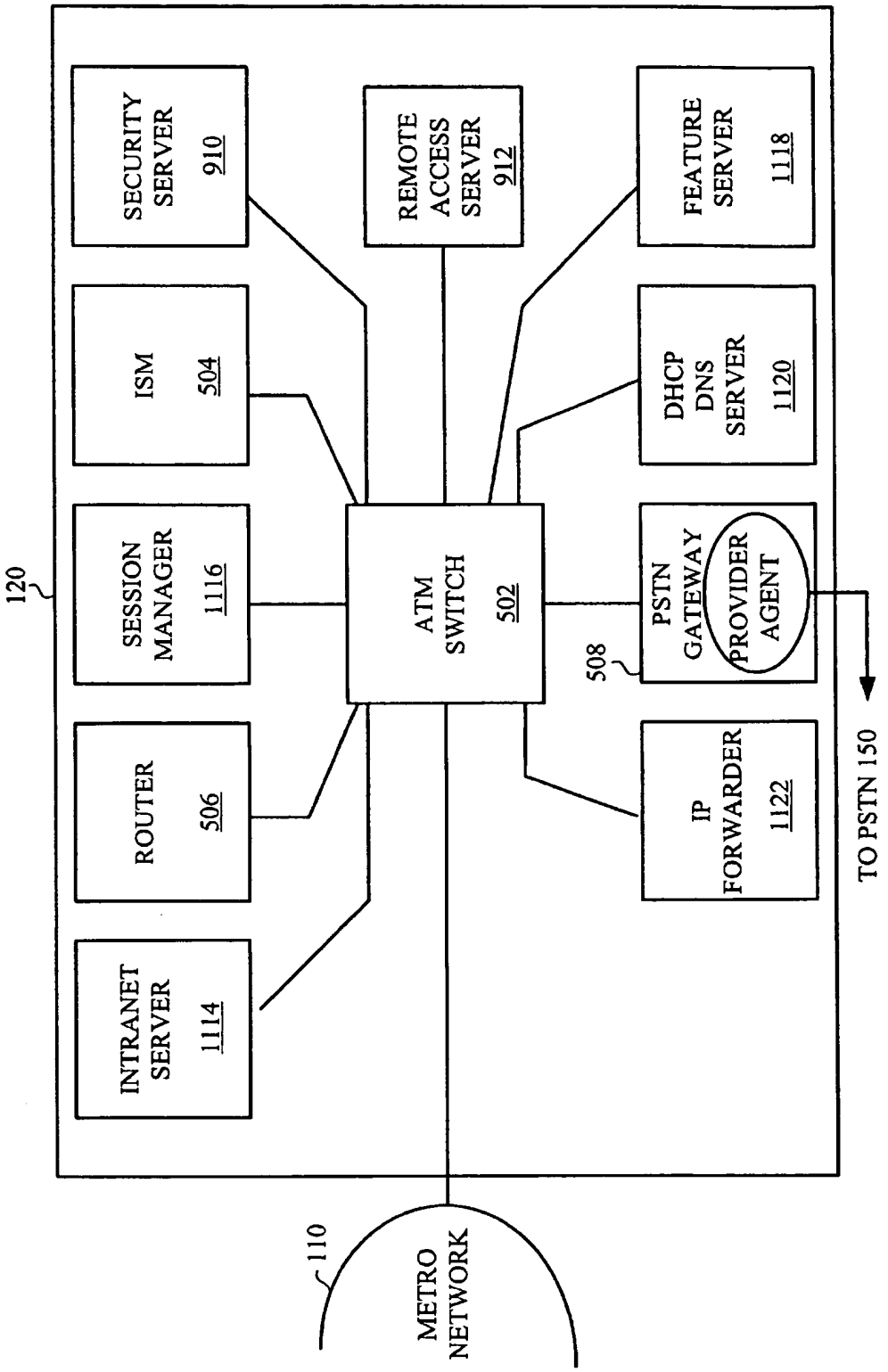

120
SECURITY SERVER 910
REMOTE ACCESS SERVER 912
FEATURE SERVER 1118
ISM 504
DHCP DNS SERVER 1120
SESSION MANAGER 1116
ATM SWITCH 502
PSTN GATEWAY
PROVIDER AGENT
508
ROUTER 506
IP FORWARDER 1122
TO PSTN 150
INTRANET SERVER 1114
110
METRO NETWORK

FIG. 11

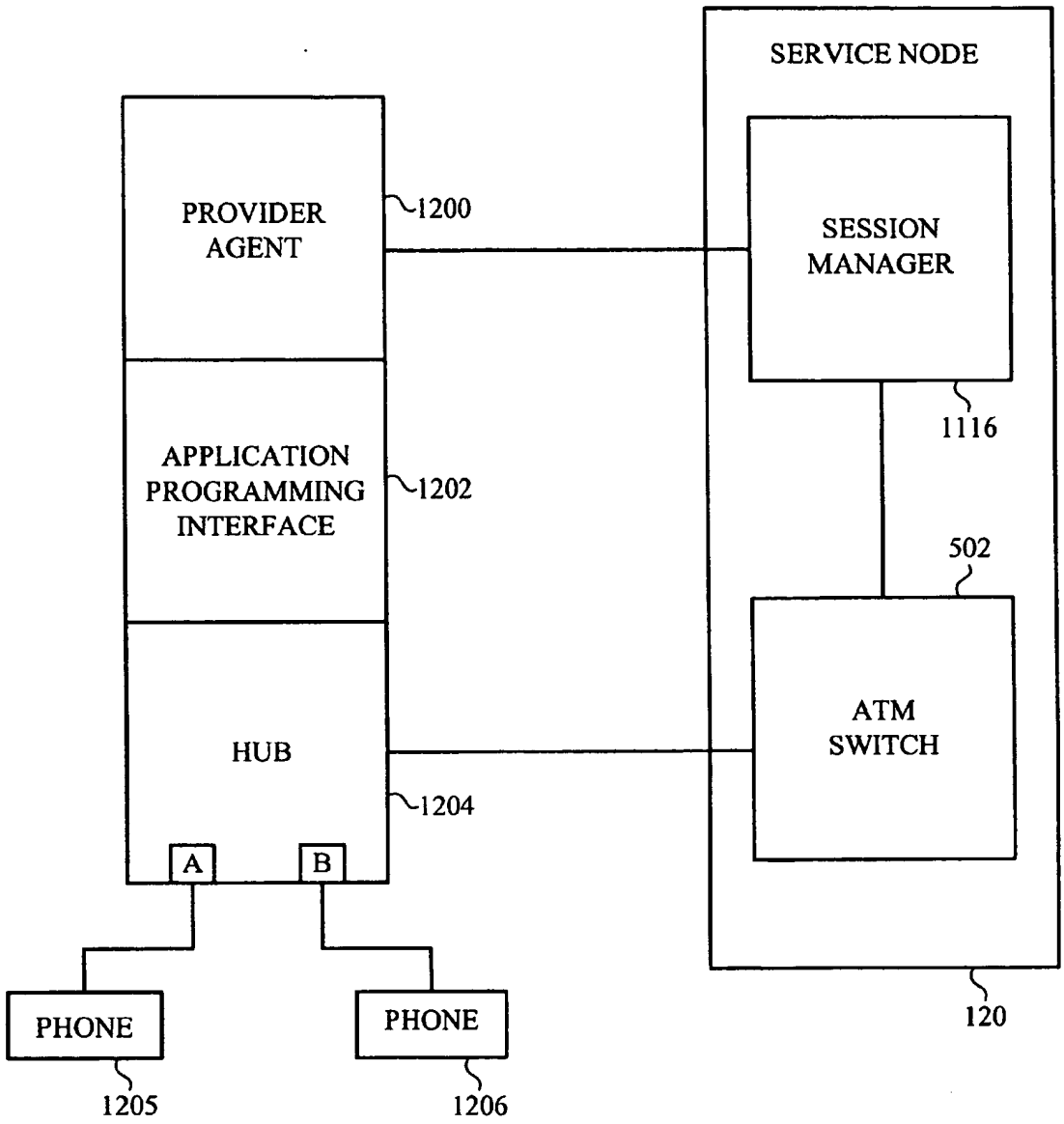

SERVICE NODE
PROVIDER AGENT
1200
SESSION MANAGER
1116
APPLICATION PROGRAMMING INTERFACE
1202
502
ATM SWITCH
HUB
1204
A
B
PHONE
PHONE
1205
1206
120

FIG. 12

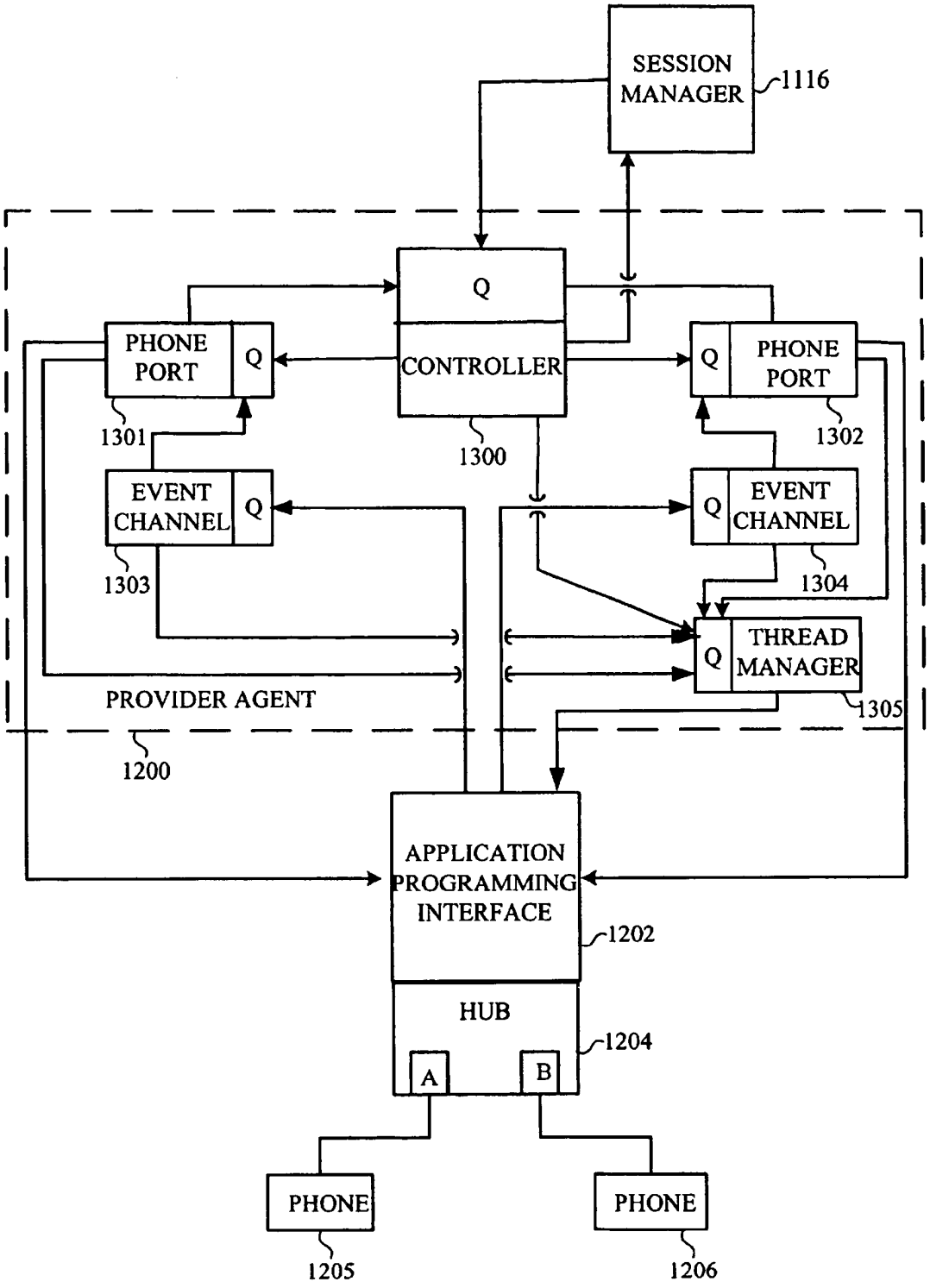

SESSION MANAGER
1116
Q
CONTROLLER
1300
PHONE PORT
Q
1301
Q
PHONE PORT
1302
EVENT CHANNEL
Q
1303
Q
EVENT CHANNEL
1304
Q
THREAD MANAGER
1305
PROVIDER AGENT
1200
APPLICATION PROGRAMMING INTERFACE
1202
HUB
1204
A
B
PHONE
1205
PHONE
1206

FIG. 13

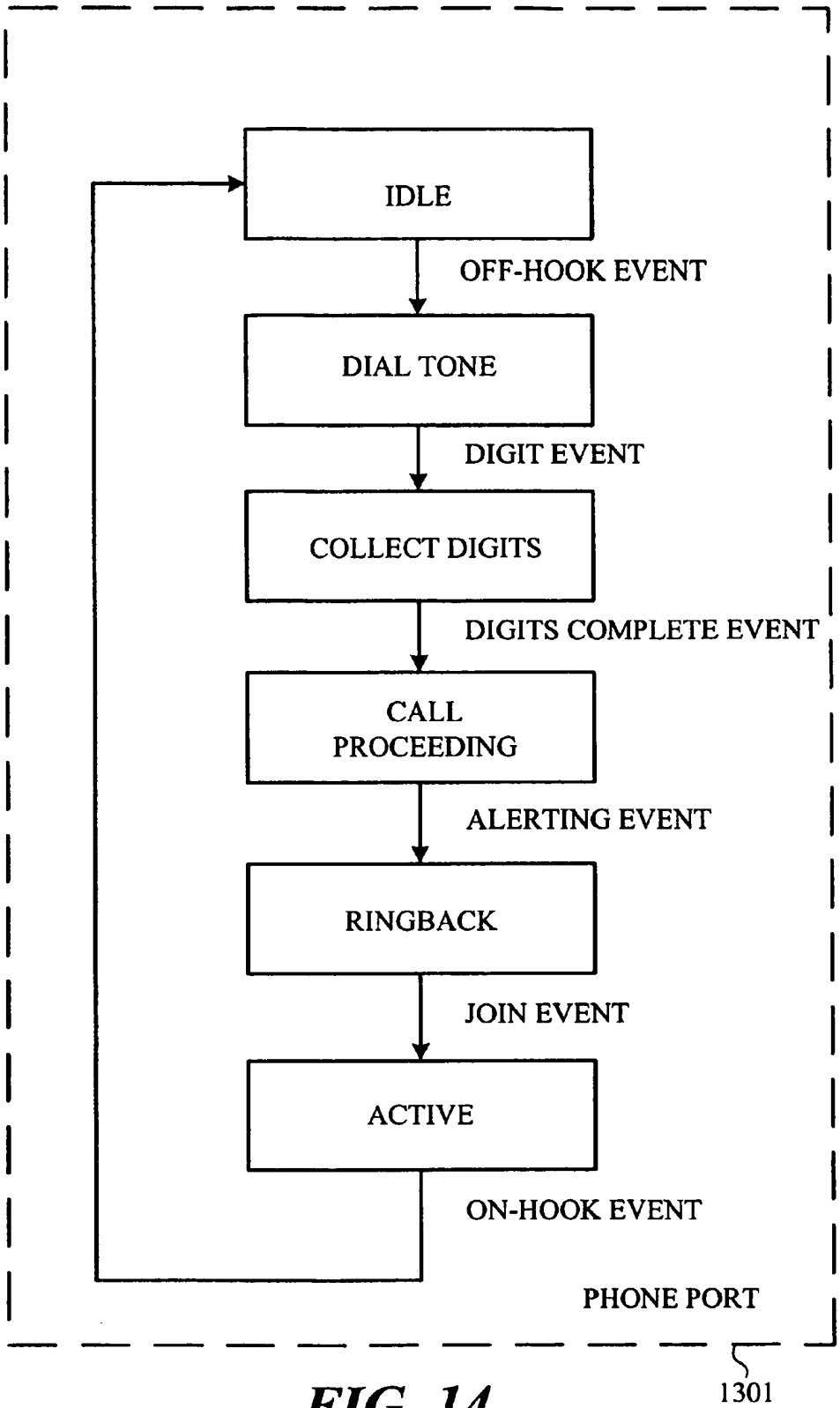

IDLE
OFF-HOOK EVENT
DIAL TONE
DIGIT EVENT
COLLECT DIGITS
DIGITS COMPLETE EVENT
CALL PROCEEDING
ALERTING EVENT
RINGBACK
JOIN EVENT
ACTIVE
ON-HOOK EVENT
PHONE PORT
1301

FIG. 14

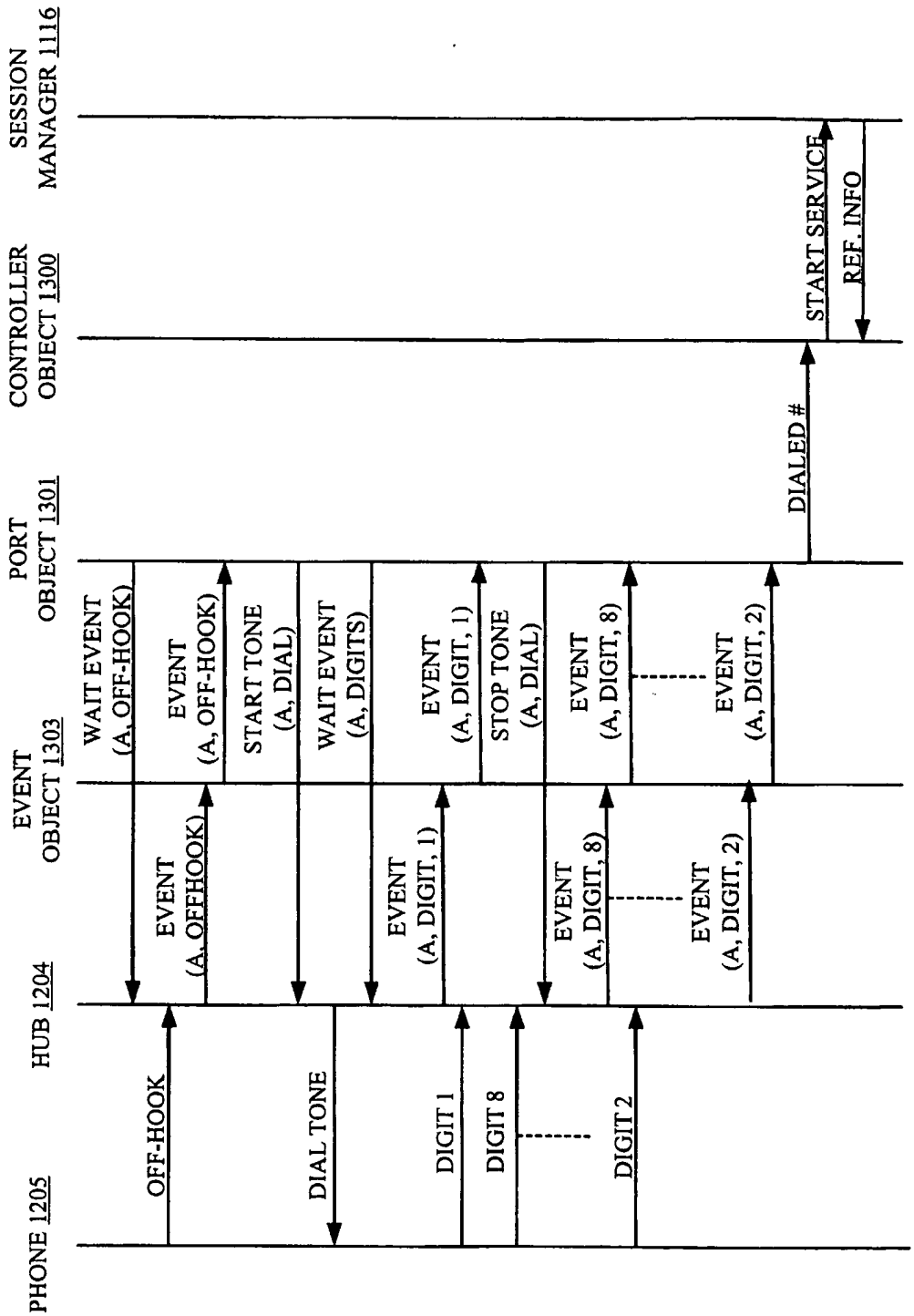

PHONE 1205
HUB 1204
EVENT OBJECT 1303
PORT OBJECT 1301
CONTROLLER OBJECT 1300
SESSION MANAGER 1116
OFF-HOOK
EVENT (A, OFFHOOK)
WAIT EVENT (A, OFF-HOOK)
EVENT (A, OFF-HOOK)
DIALED #
START SERVICE
REF. INFO
DIAL TONE
START TONE (A, DIAL)
WAIT EVENT (A, DIGITS)
DIGIT 1
EVENT (A, DIGIT, 1)
EVENT (A, DIGIT, 1)
DIGIT 8
STOP TONE (A, DIAL)
EVENT (A, DIGIT, 8)
EVENT (A, DIGIT, 8)
DIGIT 2
EVENT (A, DIGIT, 2)
EVENT (A, DIGIT, 2)

FIG. 15

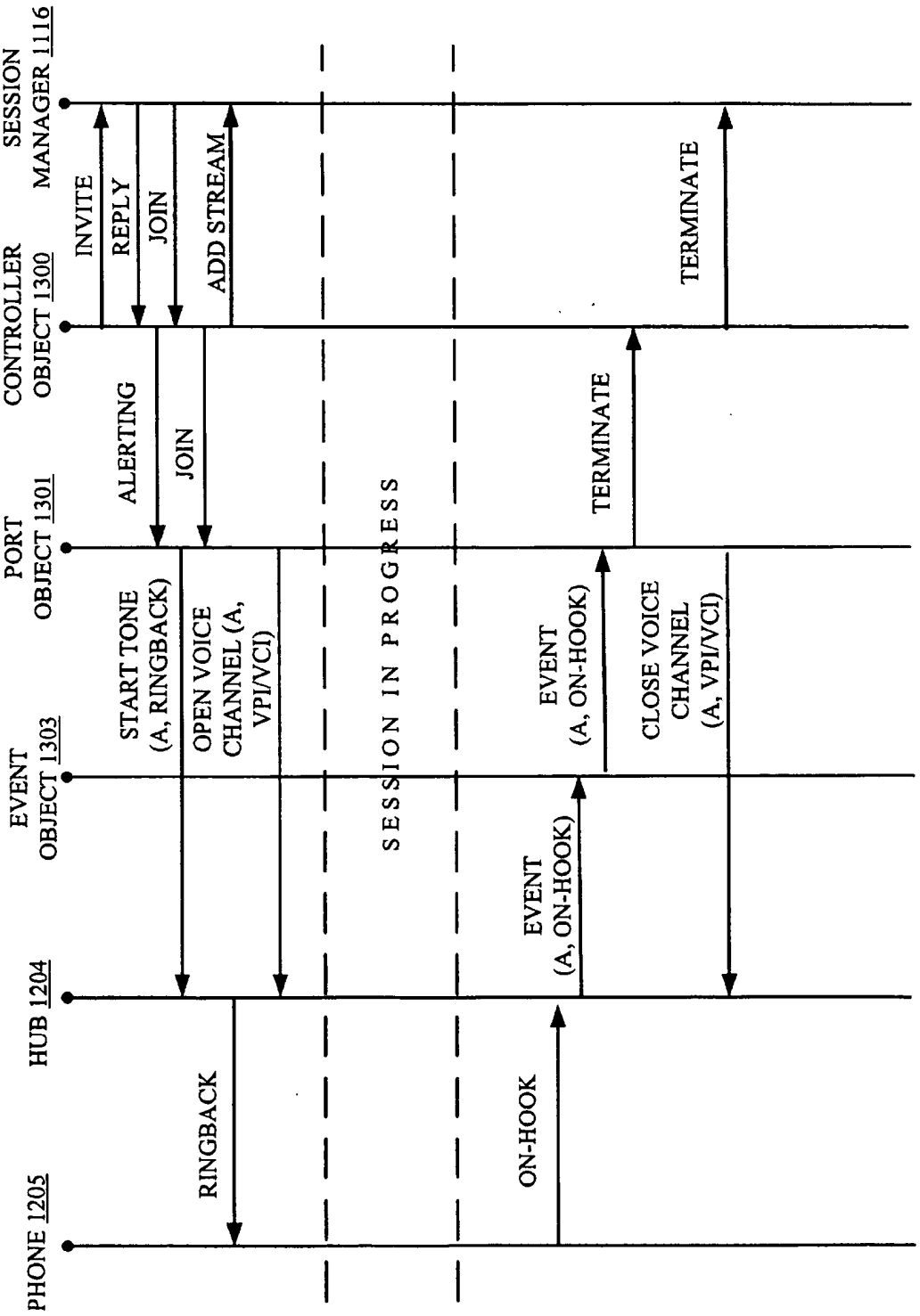

SESSION MANAGER 1116
CONTROLLER OBJECT 1300
PORT OBJECT 1301
EVENT OBJECT 1303
HUB 1204
PHONE 1205
INVITE
REPLY
JOIN
ADD STREAM
TERMINATE
ALERTING
JOIN
TERMINATE
START TONE (A, RINGBACK)
OPEN VOICE CHANNEL (A, VPI/VCI)
EVENT (A, ON-HOOK)
CLOSE VOICE CHANNEL (A, VPI/VCI)
SESSION IN PROGRESS
EVENT (A, ON-HOOK)
RINGBACK
ON-HOOK

FIG. 16

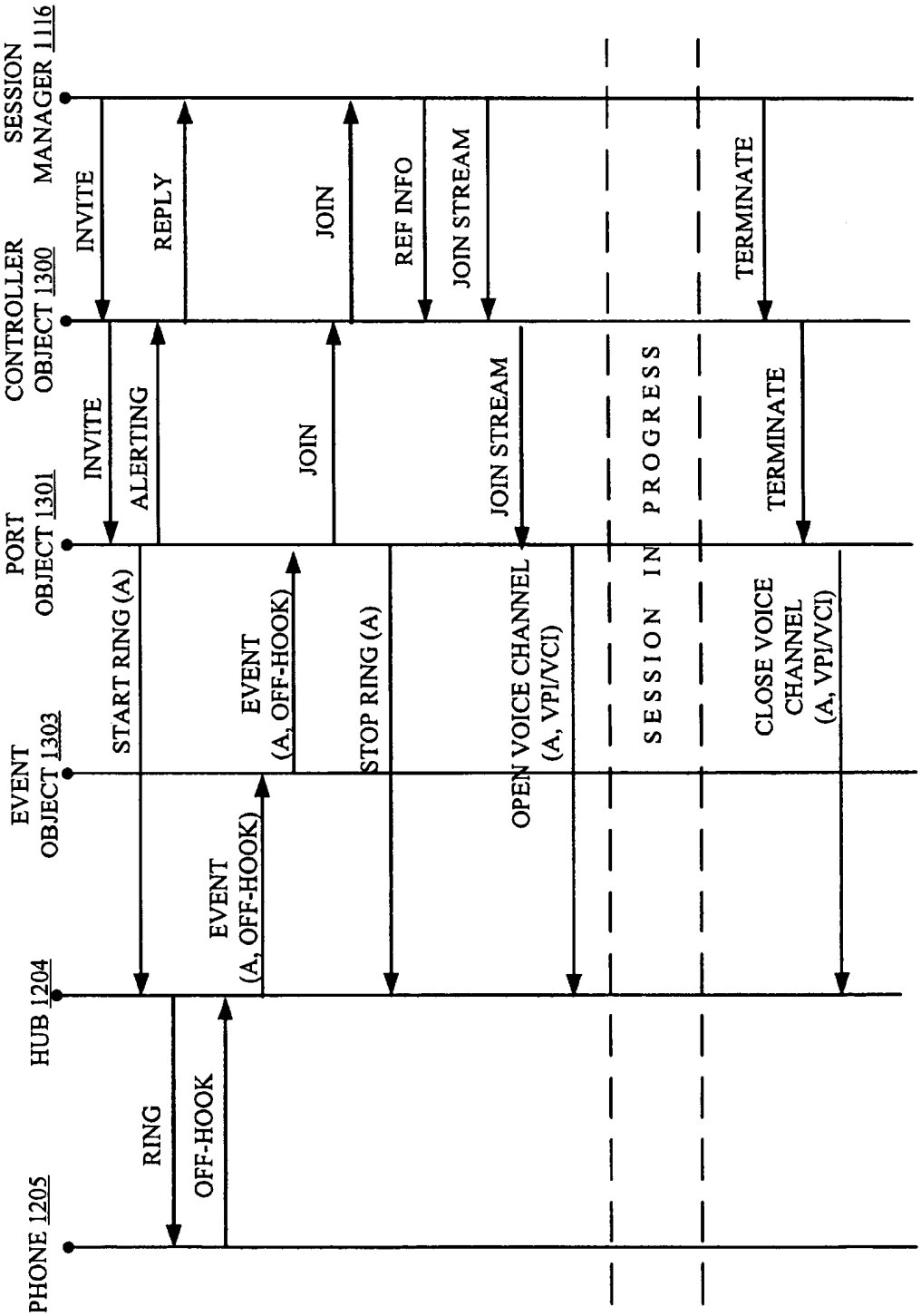

SESSION MANAGER 1116
CONTROLLER OBJECT 1300
PORT OBJECT 1301
EVENT OBJECT 1303
HUB 1204
PHONE 1205
INVITE
REPLY
JOIN
REF INFO
JOIN STREAM
TERMINATE
INVITE
ALERTING
JOIN
JOIN STREAM
TERMINATE
START RING (A)
EVENT (A, OFF-HOOK)
STOP RING (A)
OPEN VOICE CHANNEL (A, VPI/VCI)
CLOSE VOICE CHANNEL (A, VPI/VCI)
EVENT (A, OFF-HOOK)
RING
OFF-HOOK
SESSION IN PROGRESS

FIG. 17

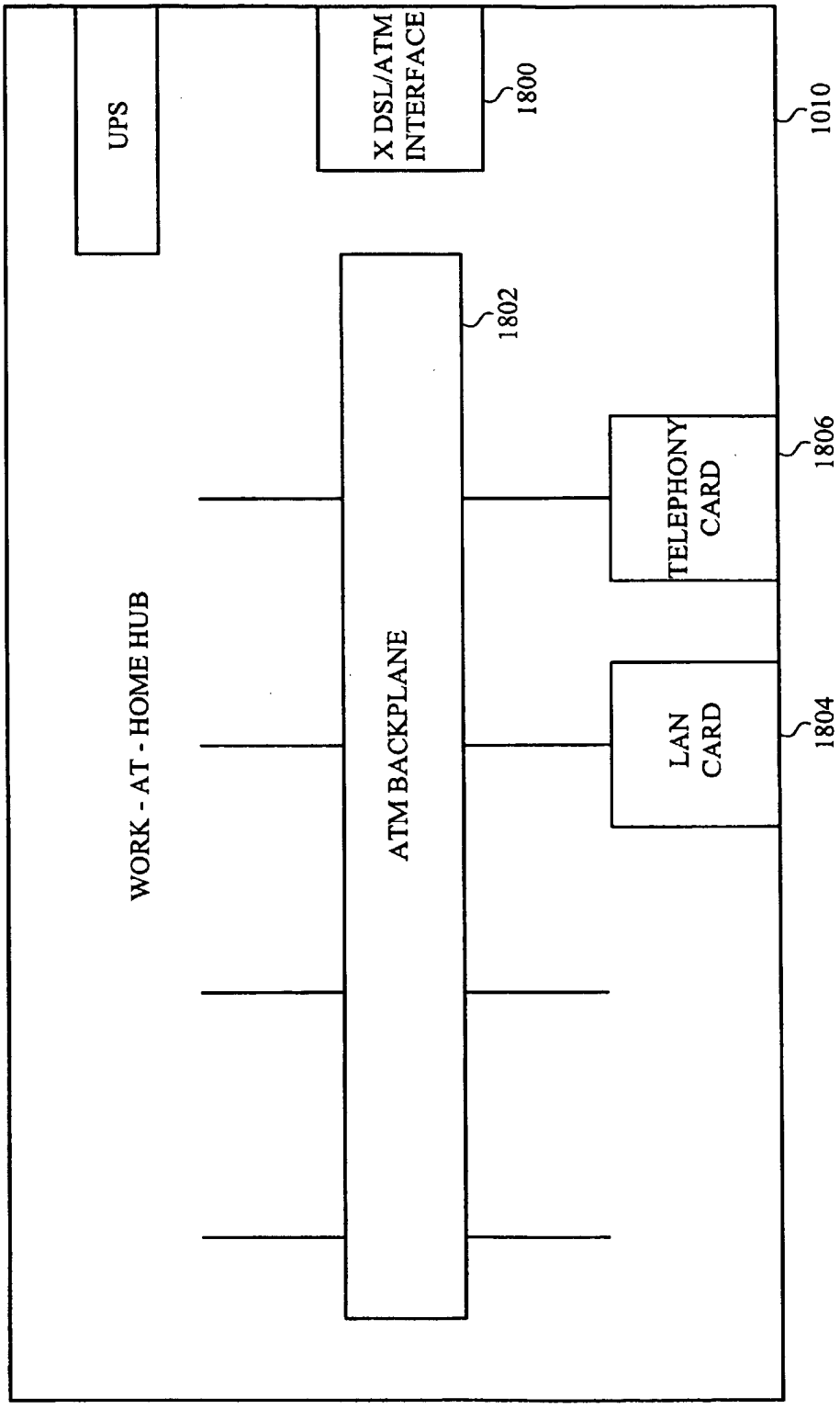

UPS
X DSL/ATM INTERFACE
1800
1010
1802
TELEPHONY CARD
1806
LAN CARD
1804
ATM BACKPLANE
WORK - AT - HOME HUB

FIG. 18

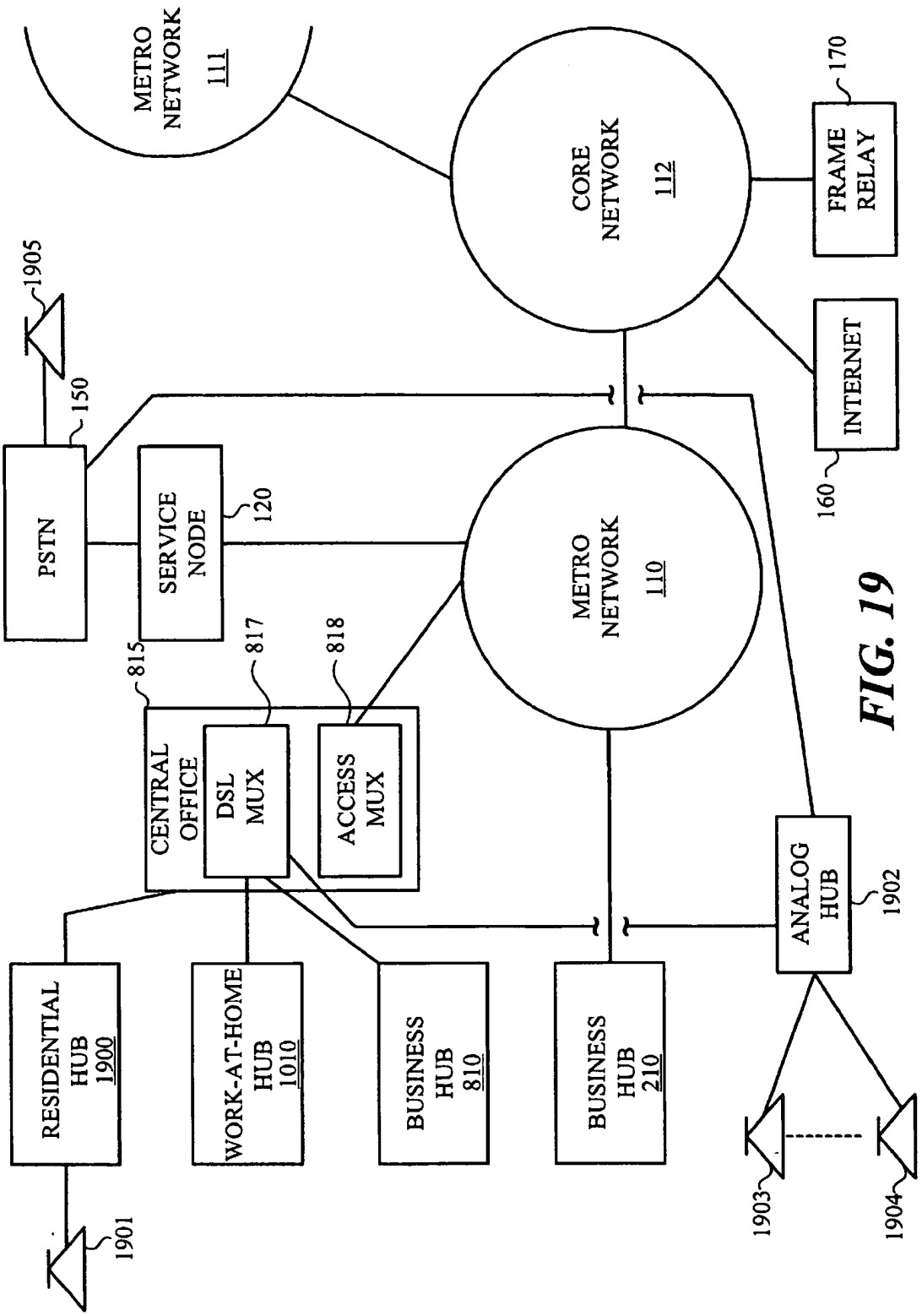

METRO NETWORK 111
CORE NETWORK 112
FRAME RELAY
170
1905
150
PSTN
SERVICE NODE
120
INTERNET
160
METRO NETWORK 110
815
817
818
CENTRAL OFFICE
DSL MUX
ACCESS MUX
ANALOG HUB
1902
RESIDENTIAL HUB 1900
WORK-AT-HOME HUB 1010
BUSINESS HUB 810
BUSINESS HUB 210
1901
1903
1904

FIG. 19

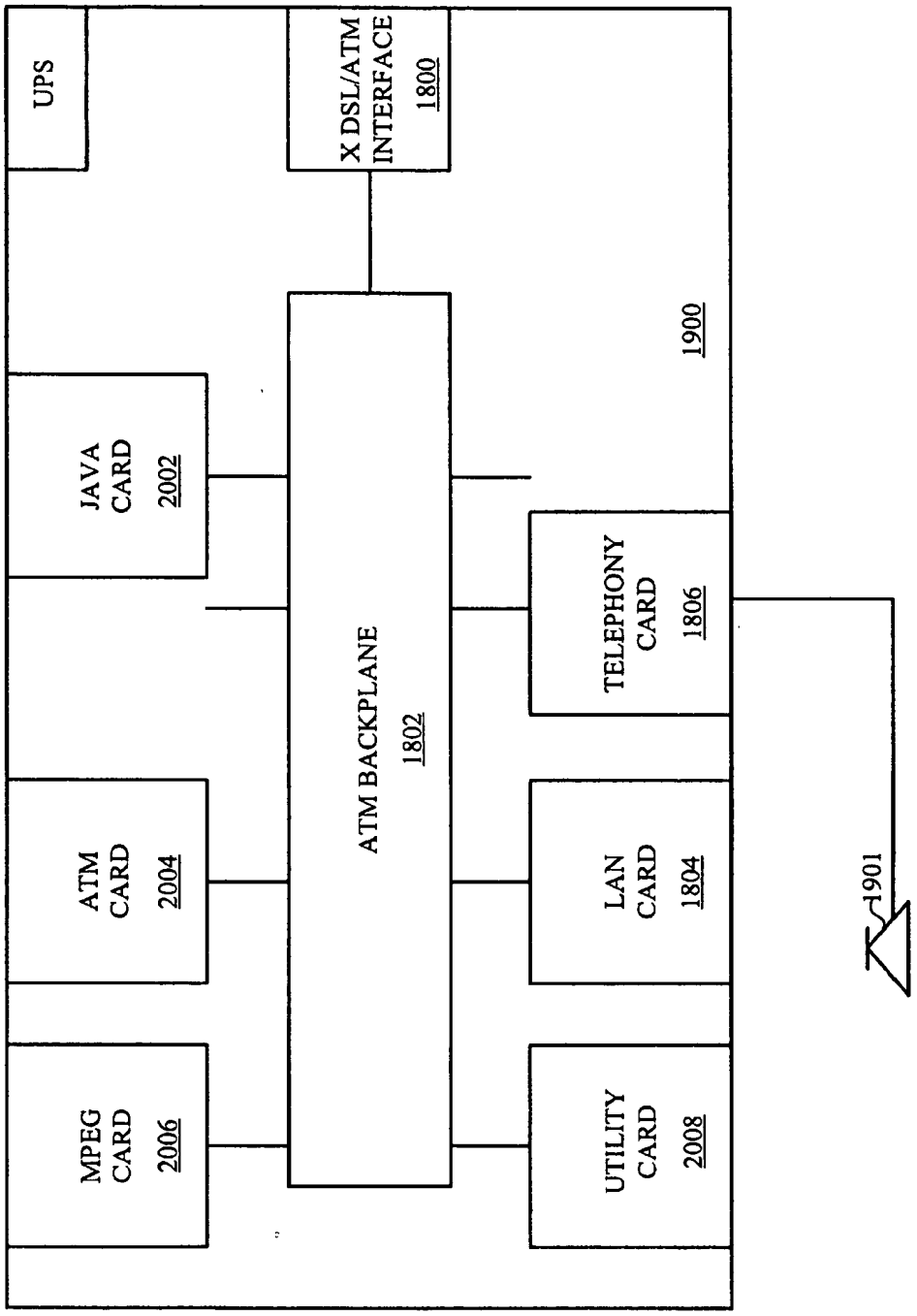

UPS
X DSL/ATM INTERFACE 1800
1900
JAVA CARD 2002
ATM BACKPLANE 1802
TELEPHONY CARD 1806
ATM CARD 2004
LAN CARD 1804
1901
MPEG CARD 2006
UTILITY CARD 2008

FIG. 20

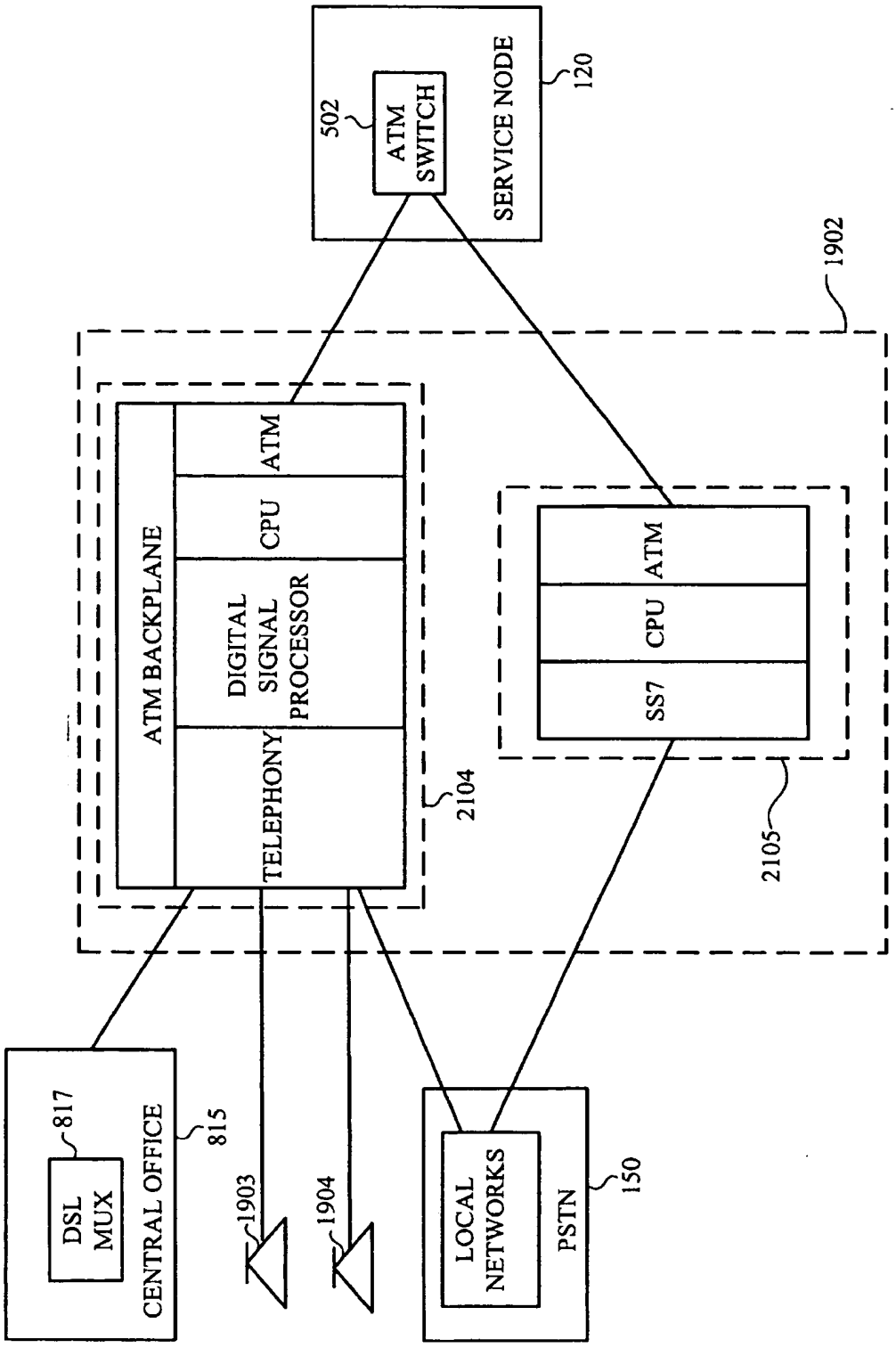

SERVICE NODE
120
502
ATM SWITCH
1902
ATM BACKPLANE
ATM
CPU
DIGITAL SIGNAL PROCESSOR
TELEPHONY
2104
SS7
CPU
ATM
2105
CENTRAL OFFICE
815
817
DSL MUX
1903
1904
PSTN
150
LOCAL NETWORKS

FIG. 21

ASYNCHRONOUS TRANSFER MODE ARCHITECTURE MIGRATION

RELATED APPLICATIONS

Not applicable.

FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not applicable.

MICROFICHE APPENDIX

Not applicable.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to communications systems, and in particular, to communications systems that provide voice telephony service using Asynchronous Transfer Mode (ATM).

2. Background

Asynchronous Transfer Mode (ATM) networks are being designed and deployed. ATM is the well-known communications format that is based on a 53-byte cell that includes a five-byte header identifying the virtual connection. ATM cells are designed to carry voice, video, and data traffic within the same communications system. ATM hubs, ATM metropolitan networks, and ATM core networks that transfer ATM cells are well known.

Businesses have increasing communications needs. Most large businesses transmit voice and data traffic over dedicated connections between their various business sites. These large businesses also transmit voice and data over switched connections provided by the Public Switched Telephone Network (PSTN). In addition, these businesses have data networks, such as intranets and frame relay systems.

Residential consumers also have increasing communications needs. These consumers want more communications channels and more bandwidth per channel. The residential consumer also desires more access to media-based services. Despite these technical advances, many residential consumers will still retain their existing telephone devices and will continue to retain conventional telephone service for these devices.

Various ATM deployments are possible to serve business and residential markets, but a problem arises when determining what ATM services should be offered initially and which services added later. This problem is complicated when the various market segments are analyzed. The large business market needs different service offerings than the smaller business market. Both business markets need different service offerings than the residential market.

Deploying a full-service ATM network that serves all markets all at once would be cost prohibitive and extremely complex. A phased approach is needed that provides a migration path from initial service offerings to the full-service ATM network. During the migration, the approach should intelligently offer services that are targeted at the different market segments.

SUMMARY

The invention overcomes the above problems by providing a series of architectures that form an incremental migration from initial ATM service offerings to a full service ATM network. The phase I architecture includes several metropolitan ATM networks that are interconnected by a core ATM network. Each metropolitan ATM network includes a service node that controls the ATM network elements that deliver the services.

In Phase I, the business hubs are connected to the metropolitan ATM network over a single ATM connection that integrates voice, data, and Internet traffic. The ATM connection contains Permanent Virtual Connections (PVCs) to various destinations, such as other business hubs, local telephone networks, long distance telephone networks, the Internet, and a frame relay network. In Phase II, the architecture is extended to the smaller business market by providing businesses with PVC-based ATM service using xDSL/ATM connections that are multiplexed at a central office and then provided to the service node over the metropolitan ATM network. In Phase III, a work-at-home hub that uses an xDSL/ATM connections is provided for telecommuting. Phase III also includes the deployment of a session manager and provider agents that interact to interpret user requests and establish the requisite communications paths using Switched Virtual Connections (SVCs). The businesses can replace some or all of their PVC-based service with more efficient SVC-based service. In Phase IV, the architecture is extended to the residential market. A residential hub is provided for residential communications over an xDSL/ATM connection through the central office to the service node. An analog hub is provided for conventional telephone service through the service node.

The first ATM architecture provides ATM PVC-based services to businesses to integrate business communications over a single ATM pipe. The first ATM architecture is comprised of networks, hubs, and Permanent Virtual Connections (PVCs). A core ATM network is connected to a first metropolitan ATM network and a second metropolitan ATM network. The first metropolitan ATM network is connected to a first business hub and a second business hub. The second metropolitan ATM network is connected to a third business hub. The business hubs interwork between ATM and the plurality of different formats, such as ethernet, T1, frame relay, internet protocol, and DS3. The first ATM architecture includes: 1) a first ATM PVC from the it first business hub to the second business hub through the first metropolitan ATM network, 2) a second ATM PVC from the first business hub to a gateway through the first metropolitan ATM network wherein the gateway interworks the second ATM PVC with a connection to a local telephone network, 3) a third ATM PVC from the first business hub to the gateway through the first metropolitan ATM network wherein the gateway interworks the third ATM PVC with a connection to a long distance telephone network, 4) a fourth ATM PVC from the first business hub to a data network through the first metropolitan ATM network and the core ATM network, and 5) a fifth ATM PVC from the first business hub to the third business hub through the first metropolitan ATM network, the core ATM network, and the second metropolitan ATM network.

The second network architecture extends the PVC-based services to the small business market and is created by adding DSL-based multiplexers and hubs. An ATM access multiplexer is connected to the first metropolitan ATM network and a Digital Subscriber Line (DSL) multiplexer is connected to the ATM access multiplexer. A fourth business hub is connected to the DSL multiplexer over a DSL/ATM connection.

The third network architecture is created by adding work-at-home hubs, a session manager, and provider agents. The

work-at-home hubs interwork between ATM and a plurality of different formats and are connected to the Digital Subscriber Line (DSL) multiplexer. A provider agent is added to the large business hubs, the small business hubs, the work-at-home hubs, and the PSTN gateway. The session manager interacts with the provider agents to establish SVC-based ATM connections in response to user requirements. In the third network architecture, a business will typically replace some or all of the PVCs used in previous architectures with SVC-based ATM connections because the SVC-based connections are more efficient from a bandwidth and cost perspective.

The fourth network architecture is created by adding a plurality of residential hubs that interwork between ATM and a plurality of different formats and that are each connected to the Digital Subscriber Line (DSL) multiplexer. The fourth network architecture also adds a plurality of analog hubs that interwork between ATM and conventional telephony and that are each connected to the metropolitan ATM network. A provider agent is added to each of the residential hubs and the analog hubs to interact with the session manager to establish SVC-based ATM connections in response to user requests. The fourth network architecture expands the full service ATM network to the residential market, but still provides conventional telephony for those who desire it.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of a Phase I architecture for some embodiments of the invention.

FIG. **2** is a block diagram of a business in some embodiments of the invention.

FIG. **3** is a block diagram of a business in some embodiments of the invention.

FIG. **4** is a block diagram of a business hub in some embodiments of the invention.

FIG. **5** is a block diagram of a service node in Phase I for some embodiments of the invention.

FIG. **6** is a block diagram of an Integrated Service Manager (ISM) server in some embodiments of the invention.

FIG. **7** is a block diagram of a service node, businesses, and the Public Switched Telephone Network (PSTN) in some embodiments of the invention.

FIG. **8** is a block diagram of a Phase II addition to the Phase I architecture in some embodiments of the invention.

FIG. **9** is a block diagram of a service node in Phase II for some embodiments of the invention.

FIG. **10** is a block diagram of a Phase III addition to the Phase II architecture in some embodiments of the invention.

FIG. **11** is a block diagram of a service node in Phase III for some embodiments of the invention.

FIG. **12** is a block diagram of a service node and a generic hub including a provider agent for some embodiments of the invention.

FIG. **13** is a block diagram of a software architecture for a provider agent in some embodiments of the invention.

FIG. **14** is a block diagram of a telephone port software object state machine in a provider agent for some embodiments of the invention.

FIG. **15** is a message sequence chart depicting system operation in some embodiments of the invention.

FIG. **16** is a message sequence chart depicting system operation in some embodiments of the invention.

FIG. **17** is a message sequence chart depicting system operation in some embodiments of the invention.

FIG. **18** is a block diagram of a Work-at-Home (WAH) hub in some embodiments of the invention.

FIG. **19** is a block diagram of a Phase IV addition to the Phase III architecture in some embodiments of the invention.

FIG. **20** is a block diagram of a residential hub in some embodiments of the invention.

FIG. **21** is a block diagram of an analog hub in some embodiments of the invention.

DETAILED DESCRIPTION

On the figures, the first digit(s) of a reference number for an element indicate the first figure that the element appears on. The following are hereby incorporated by reference into this Patent Application: U.S. Pat. No. 6,141,339 assigned to the same entity as this Patent Application; U.S. Pat. No. 6,229,803 assigned to the same entity as this Patent Application; U.S. patent application Ser. No. 09/129,268 entitled "Telecommunications Provider Agent", and assigned to the same entity as this Patent Application; and U.S. patent application Ser. No. 09/129,248 entitled "Asynchronous Transfer Mode System for Providing Telephony Service" now U.S. Pat. No. 6,407,997, and assigned to the same entity as this Patent Application.

The invention comprises a series of architectures that are implemented in four phases to provide a migration path from an initial ATM service offering to a full service ATM network. The initial ATM network includes several metropolitan ATM networks that are interconnected by a core ATM network. Each metropolitan ATM network includes a service node that controls ATM network elements to deliver services. In Phase I, a business hub that is connected to the metropolitan ATM network integrates voice, data, and Internet traffic over a single ATM connection that contains permanent Virtual Connections (PVCs) to various destinations, such as other business hubs, a gateway to local and long distance networks, the Internet, a frame relay network. In Phase II, the architecture is extended to smaller business markets. Businesses are provided with the PVC-based ATM service using xDSL/ATM connections that are multiplexed at a central office and then provided to the service node over the metropolitan ATM network. A remote dial-in feature is also added. In Phase III, a work-at-home hub is provided for telecommuting. The work-at-home hub uses an xDSL/ATM connection through the central office to the service node. Phase III also includes the deployment of a session manager and provider agents that interact to interpret user requests and establish the requisite communications paths using Switched Virtual Connections (SVCs). The business can replace existing some or all PVC-based service with more efficient SVC-based service. In Phase IV, the architecture is extended to the residential market. A residential hub is provided for residential communications over an xDSL/ATM connection through the central office to the service node. An analog hub is provided for conventional telephone service through the service node.

Phase 1 Network Architecture—FIG. 1

FIG. **1** depicts a Phase I architecture for an Asynchronous Transfer Mode (ATM) network **100** for some embodiments of the invention. The ATM network **100** interconnects businesses **101, 102, 103,** and **104** with each other and with the Public Switched Telephone Network (PSTN) **150,** the Internet **160,** and the frame relay network **170.** The ATM network **100** is comprised of metropolitan ATM networks **110–111,** a

core ATM network **112**, and service nodes **120–121**. The metropolitan ATM network **110** is connected to the businesses **101–102**, the service node **120**, and the core ATM network **112**. The metropolitan ATM network **111** is connected to the businesses **103–104**, the service node **121**, and the core ATM network **112**. The service nodes **120–121** are connected the PSTN **150**. The core ATM network **112** is connected to the Internet **160** and the frame relay network **170**.

The businesses **101–104** are commercial enterprises that have equipment for exchanging ATM cells with the ATM network **100**. The metropolitan ATM networks **110** and **111** are Broadband Metropolitan Area Networks (BMAN) that are comprised of four-fiber, bi-directional, line-switched, self-healing Synchronous Optical Network (SONET) rings that transport ATM cells. The core ATM network **112** is a Wide Area Network (WAN) that is comprised of four-fiber, bi-directional, line-switched, self-healing SONET rings that transport ATM cells. An example of an ATM switch for the core ATM network **112** is the NEC model **20**. Metropolitan ATM networks and core ATM networks are known in the art. The service nodes are network sites that contain ATM switches and network operations equipment. The PSTN **150** represents the well known local and long distance telephone networks, such as Sprint and Bell Atlantic. The Internet **160** is the well known public network based on the Internet Protocol (IP). The Internet **160** could include an Internet Service Provider (ISP), such as SprintLink. The frame relay network **170** is a data network based on the well known frame relay protocol.

In operation, the business **101** exchanges ATM cells containing voice and data with the service node **120** over the metropolitan ATM network **110**. The service node **120** exchanges the ATM cells with the other businesses **102–104** over the metropolitan ATM networks **110–111** and the core ATM network **112**. The service node **120** exchanges the voice and data traffic in the ATM cells with the PSTN **150**, the Internet **160**, and the frame relay network **170**. The businesses **102–104** exchange ATM cells with the ATM network **100** in a similar manner.

Business Systems—FIGS. **2–4**

FIG. **2** depicts the business **101** for some embodiments of the invention. The business **101** is connected to the metropolitan ATM network **110**. The business **101** is comprised of Customer Premise Equipment (CPE) **201**, **202**, and **203** that are connected to a business hub **210**. The business hub **210** is connected to the metropolitan ATM network **110**. The CPE **201–203** are conventional business communications equipment, such as Local Area Networks (LANs), PBX devices, key systems, telephones, computers, fax machines, and servers. The business hub **210** is a device for exchanging voice and data traffic in various protocols with the CPE **201–203**. The business hub **210** interworks these various protocols with the ATM protocol and exchanges the resulting ATM cells with the service node **120** (not shown) over the metropolitan ATM network **110** using PVCs. As a result, the business hub **210** handles all of the communications of the business **101** over a single ATM interface. The business hub **210** could be adapted from the FORE Systems ASX-1000.

FIG. **3** depicts the CPE of the business **101** for some embodiments of the invention, but the invention is not restricted to this particular configuration. The business CPE is comprised of a LAN **301**, a key system **302**, a channel bank **303**, a PBX **304**, and the business hub **210**. Telephones are shown connected to the key system **301** and the PBX **304**, but fax machines, computers, and other devices could also be connected. The LAN **301** is connected to the data interface of the business hub **210**. The key system **302** is connected to the channel bank **303**, and the channel bank **303** is connected to the voice interface of the business hub **210**. The PBX **304** is connected to the voice interface of the business hub **210**. The voice and data interfaces of the business hub **210** are coupled to an ATM interface. The ATM interface exchanges the resulting ATM cells with the service node **120** (not shown) over the metropolitan ATM network **110** using PVCs.

The LAN **301** is a short distance communications network that is typically used to link computers and peripheral devices in a building or campus. The LAN **301** would use a physical layer protocol and a data layer protocol to transmit data. Some examples of physical layer protocols and data layer protocols are listed and described below:

- Ethernet—an IEEE standard 10 or 100 megabit/second LAN using copper wire or co-axial cable.
- Fiber Distributed Data Interface (FDDI)—an ANSI standard 100 megabit/second fiber optic LAN using a counter-rotating token ring topology.
- T1/V.35/RS-422—a high speed interface for copper wiring. T1 is a digital link operating at the Digital Service level one (DS1) speed of 1.544 megabits per second. V.35 is an ITU standard interface between a packet network and a network access device. RS-422 is a standard describing the electrical characteristics for a balanced electrical implementation of a high-speed data transmission circuit.
- High Speed Serial Interface (HSSI)—a serial data communications interface optimized for speeds up to 52 megabits/second.
- Digital Service Level 3 (DS3)—28 T1 channels operating at 44.736 megabits/second.
- T1—a digital link operating at the Digital Service level one (DS1) speed of 1.544 megabits per second.
- Asynchronous Transfer Mode (ATM)—a switching technology using 53 byte cells that transport voice and data.
- Internet Protocol (IP)—a message routing protocol. Used by the "Internet."
- Frame Relay (FR)—a switching technology for variable length packets.
- Inverse Multiplex ATM (IMA)—an inverse multiplexed ATM connection.
- OC-3 and OC-12—SONET signals operating at 155 and 622 megabits/second respectively.

The LAN **301** may include an internal router that supports internal data traffic for the business, such as an intranet. The internal router is typically connected through a firewall to a web server and the web server is connected to the Internet **160**. In some embodiments of the invention, internal data traffic is exchanged between the internal router on the LAN **301** and the business hub **210**, and Internet traffic is exchanged between the web server on the LAN **301** and the business hub **210**. The internal data traffic is provided to the other business sites over ATM PVCs. The Internet traffic is provided to the Internet **160** over another ATM PVC.

The key system **302** is a device that supports multiple telephones. Typically, telephones that are connected to a key system have buttons for selecting internal or external lines. The channel bank **303** is a multiplexer that connects multiple analog voice lines from the key system **302** over a higher speed digital link to the business hub **210**. The PBX **304** is a private branch exchange that supports multiple telephones. The PBX **304** can interconnect one telephone at the business

with another telephone at the business. The PBX **304** can also connect these telephones to the business hub **210**.

FIG. **4** depicts the business hub **210** for some embodiments of the invention. The business hub **210** is shown with numerous interfaces, but all of the interfaces are not required. Various combinations and sub-combinations of the interfaces could be used to access the ATM interface. The Internet Protocol (IP) interface can be coupled to any of the following physical layer interfaces: ethernet, FDDI, V.35/RS-422, HSSI, DS3, and T1. The Frame Relay (FR) interface can be coupled to any of the following physical layer interfaces: V.35/RS-422, HSSI, DS3, and T1. The ATM interface can be coupled to DS3 and T1 physical layer interfaces. The ATM interface includes the voice interface, and the voice interface can be coupled to a T1 physical layer interface and an Integrated Services Digital Network (ISDN) Primary Rate Interface (PRI). The business CPE are connected to the physical interfaces and exchange IP, FR, ATM, and voice with the business hub **210**. The IP interface and the FR interface are coupled to the ATM interface. The ATM interface is coupled to one of the physical interfaces to the metropolitan ATM network **110**. The possible physical interfaces to the metropolitan ATM network **110** include: IMA, T1, NxT1, DS3, OC-3, and OC-12. In operation, CPE at the business exchange voice and data through one of the physical layer ports to the IP, FR, or ATM interface. The IP and FR interface exchange the data with the ATM interface. The FR interface uses FRF.5 and FRF.8 for ATM interworking. The ATM interface exchanges the data with the service node through one of the physical interfaces to the metropolitan ATM network **110**.

Phase I Service Node—FIGS. **5–7**

FIG. **5** depicts the service node **120** for some embodiments of the invention. The service node **120** is connected to the metropolitan ATM network **110** and the PSTN **150**. The service node **120** is comprised of an ATM switch **502**, an Integrated Services Management (ISM) server **504**, a router **506**, and a PSTN gateway **508**.

The ATM switch **502** has a processor, power supply, and interface redundancy. The ATM switch **502** supports the User to Network Interface (UNI) 3.1 defined for service classes CBR,VBR, and UBR. The ATM switch **502** uses traffic management features such as weighted fair queuing and early packet discard to prioritize flows, protect voice from cell delay variation, and protect data from cell loss. One example of the ATM switch **502** is the Nortel Vector.

The ATM switch **502** routes Permanent Virtual Circuits (PVCs) from the business hub **210** to various points. PVCs are established from the business hub **101** to the business hub **102**, the PSTN gateway **508**, and the core ATM network **112**. The core ATM network extends some of the PVCs to the other service node **121**, the internet **160**, and the frame relay network **170**. An ATM switch in the other service node **121** extends some of the PVCs to other businesses **103–104** or the PSTN **150**.

The router **506** exchanges IP traffic with the businesses **101–102** over PVCs. The router **506** combines the IP traffic from the various businesses and exchanges the combined IP traffic with the Internet **160** over an ATM PVC using the Unidentified Bit Rate (UBR) standard. The bearer interface should support UNI **3.0** and **3.1**. The ATM PVC is carried within a SONET OC-3 or OC-12 connection to a router at an ISP. The router **506** also provides a WWW cache.

FIG. **6** shows depicts ISM server **504** for some embodiments of the invention. The ISM server **504** provides network management capability for service assurance and service delivery. The ISM server **504** manages the ATM switch **502** through provisioning, fault control, and accounting. The ISM server **502** also provides a user interface for subscription, operations, and services. The ISM server **504** provisions, manages, operates, and maintains the network. The ISM server **504** creates the IP infrastructure and the ATM infrastructure. The ISM server **504** adds and removes customer sites from the service node data base. The ISM server **504** provisions PVCs between endpoints of the ATM network, and manages fault conditions. The ISM server **504** has user interfaces for web-browsers, Java, and ethernet; and has network interfaces for ethernet, SNMP, CMIP, and TL-1.

The ISM server **504** is comprised of a connection manager **602**, a performance manager **603**, and a web server **604**. The connection manager **602** tracks the status of network elements and connections and allocates the network elements and connections in response to user service requirements. The connection manager directs the performance manager **603** to control the various network elements. The performance manager **603** includes various software components. Element proxies configure ports, links, cross-connects, and routing tables in the network elements as required by the connection manager **602**. Element agents interface with the network elements for other operations, such as fault, configuration, accounting, and security management activities that are required by the connection manager **602**. A fault component receives the fault information from the element proxies and the element agents and correlates this information into a common record for the connection manager **602**. An accounting component collects accounting and performance information from the element proxies and agents and provides the information to the fault component, billing, and other systems through an event forwarding discriminator. Various applications are also included in performance manager **603**, such as an object-oriented database, a Distributed Processing Environment (DPE) trader service based on the Common Object Request Broker Architecture (CORBA), a CORBA-based notification service that guarantees delivery of system events, and a CORBA-based peer recovery service.

The web server **604** includes various software components. A subscription component allows the customer to view the subscribed services and customer information. An interface component allows the customer to view a graphical depiction of the network and network elements involved in the subscribed services to indicate network element performance. A dashboard component allows easy customer access to frequently used services. For example, the dashboard may contain a telephone manager to access caller ID information, phone logs, and missed call information. A service component will provide customer access to applications, such as video-conferencing, virtual private networks, and collaboration environments. A troublereport component allows the customer to report and check the status of trouble tickets, and allows the network administrators to update status.

FIG. **6** depicts the PSTN gateway **508** in the Service Node **120** and the PSTN **150** for some embodiments of the invention. The PSTN gateway **508** provides TDM to ATM interworking between the ATM network **100** and the PSTN **150**. In phase I, the PSTN gateway **508** interworks ATM to TDM for ATM adaption layer **1** circuit emulation of T1 connections. The PSTN gateway also supports echo cancellation, fault tolerant hardware, NEBS compliance, and SNMP management.

The PSTN **150** is comprised of local and long distance networks that are comprised of telephone switches. The long distance network is comprised of class **4** switches and may

be connected to a business over a dedicated line such as a T1. The local network includes both class switches that connect to the telephones and class 4 tandem switches that connect to the long distance network. Class 5 switches may be directly connected to the long distance network as well. The local network may also be connected to a business over a dedicated line, such as a PRI.

The PSTN gateway **508** is connected to switches in both the local and the long distance networks. The business CPE business separates the local telephone traffic and long distance 1t telephone traffic into separate T1 or PRI connections to the business hub **210**. The business hub **210** places the local traffic in an ATM PVC to the PSTN gateway **508** and places the long distance traffic into a separate ATM PVC to the PSTN gateway **508**. The PSTN gateway **508** a converts the local traffic from ATM to TDM and connects the local traffic to the local network in the PSTN **150**. The PSTN gateway **508** converts the long distance traffic from ATM to TDM and connects the long distance traffic to the long distance network in the PSTN **150**. The long distance network typically connects the call to another local network in the PSTN **150** for connection to a telephone.

Phase I Traffic Flows—FIGS. **1–7**

There are several traffic flows through the ATM network **100** for the businesses **101–104**. Traffic is referred to as on-net and off-net. On-net to on-net traffic originates and terminates at a hub of the ATM network **100**. Traffic originating and terminating at the businesses **101–104** is on-net to on-net. On-net to off-net traffic originates at a hub of the network **100**, but terminates elsewhere, such as through the PSTN **150**. Off-net to on-net traffic terminates at hub of the network **100**, but originates elsewhere, such as the Internet **160**. Traffic may be either dedicated or switched. Dedicated traffic flows between two pre-determined points. The endpoints for switched traffic are defined at the time of the communication and a network sets-up the connection.

Dedicated voice traffic can flow between any of the businesses **101–104** as might occur for a large corporation with multiple regional offices that are connected by private lines. The ATM network **100** transports voice traffic over PVCs between the businesses **101–104**. The PVC between the business **101** to the business **102** is established: 1) from the business hub **210** in the business **101** through the metropolitan ATM network **110** to the ATM switch **502** in the service node **120**, and 2) from the ATM switch **502** in the service node **120** through the metropolitan ATM network **110** to the business hub in the business **102**. The PVCs between the business **101** and the businesses **103–104** are established: 1) from the business hub **210** in the business **101** through the metropolitan ATM network **110** to the ATM switch **502** in the service node **120**, 2) from the ATM switch **502** in the service node **120** through the metropolitan ATM network **110**, the core ATM network **120**, and the metropolitan ATM network **111** to the ATM switch in the service node **121**, and 3) from the ATM switch in the service node **121** through the metropolitan ATM network **111** to the business hubs in the businesses **103–104**. The other businesses **102–104** could be connected in a similar manner.

Switched voice traffic can flow between any of the businesses **101–104**. The ATM network **100** transports the voice traffic over PVCs between the businesses **101–104** and the PSTN **150**. The PSTN **150** transports the voice traffic over conventional switched connections between the service node **120** and the service node **121**. The PVCs between the businesses **101–104** and the PSTN **150** are established: 1) from the business hubs in the businesses **101–102** through the metropolitan ATM network **110** to the ATM switch **502** in the service node **120**, 2) from the ATM switch **502** in the service node **120** to the PSTN gateway **508** in the service node **120**, 3) from the business hubs in the businesses **103–104** through the metropolitan ATM network **111** to the ATM switch in the service node **121**, and 4) from the ATM switch in the service node **121** to the PSTN gateway in the service node **121**. The PSTN gateways in the service nodes **120–121** connect to the PSTN **150** using conventional Time Division Multiplexing (TDM) connections and associated Signaling System #7 (SS7) links. In some embodiments, local and/or long distance networks of the PSTN **150** are integrated with the ATM network **100** into a single communications network.

Dedicated voice traffic can flow between any hub and any off-net location. The ATM network **100** transports the voice traffic over a PVC between the business **101** and the PSTN **150**. The PSTN **150** transports the voice traffic and over a conventional dedicated connection between the service node **120** and the off-net location. The PVC between the business **101** and the PSTN **150** is established: 1) from the business hub **210** in the business **101** through the metropolitan ATM network **110** to the ATM switch **502** in the service node **120**, and 2) from the ATM switch **502** in the service node **120** to the PSTN gateway **508** in the service node **120**. The PSTN gateway **508** is connected to the PSTN **150** over a dedicated TDM link, such as a T1. In some embodiments, local and/or long distance networks of the PSTN **150** are integrated with the ATM network **100** into a single communications network. The other businesses **102–104** could be connected in a similar manner.

Switched voice traffic can flow between any hub and any off-net location. The ATM IS network **100** transports the voice traffic over a PVC between the business **101** and the PSTN **150**. The PSTN **150** transports the voice traffic over a conventional switched connection between the service node **120** and the off-net location. The PVC between the business **101** and the PSTN **150** is established: 1) from the business hub **210** in the business **101** through the metropolitan ATM network **110** to the ATM switch **502** in the service node **120**, and 2) from the ATM switch **502** in the service node **120** to the PSTN gateway **508** in the service node **120**. The PSTN **508** gateway in the service node **120** connects to the PSTN **150** using conventional Time Division Multiplexing (TDM) connections and associated Signaling System #7 (SS7) links. In some embodiments, local and/or long distance networks of the PSTN **150** are integrated with the ATM network **100** into a single communications network. The other businesses **102–104** could be connected in a similar manner.

Data traffic can flow between any of the businesses **101–104**. The ATM network **100** transports the data traffic over PVCs between the businesses **101–104**. The PVC between the business **101** to the business **102** is established: 1) from the business hub **210** in the business **101** through the metropolitan ATM network **110** to the ATM switch **502** in the service node **120**, and 2) from the ATM switch **502** in the service node **120** through the metropolitan ATM network **110** to the business hub in the business **102**. The PVCs between the business **101** and the businesses **103–104** are established: 1) from the business hub **210** in the business **101** through the metropolitan ATM network **110** to the ATM switch **502** in the service node **120**, 2) from the ATM switch **502** in the service node **120** through the metropolitan ATM network **110**, the core ATM network **120**, and the metropolitan ATM network **111** to the ATM switch in the service node **121**, and 3) from the ATM switch in the service node **121** through the metropolitan ATM network **111** to the

business hubs in the businesses **103–104**. The other businesses **102–104** could be connected in a similar manner.

Internet data traffic can flow between any of the businesses **101–104**. The ATM network **100** transports the data traffic over PVCs between the businesses **101–104** and the Internet **160**. The Internet **160** transports the data traffic over conventional IP connections between the service node **120** and the service node **121**. The PVCs between the businesses **101–104** and the Internet **160** are established: 1) from the business hubs in the businesses **101–102** through the metropolitan ATM network **110** to the ATM switch **502** in the service node **120**, 2) from the ATM switch **502** in the service node **120** to the router **506** in the service node **120**, 3) from the router **506** in the service node **120** through the metropolitan ATM network **110** and the core ATM network **112** to the Internet **160**, 4) from the business hubs in the businesses **103–104** through the metropolitan ATM network **111** to the ATM switch in the service node **121**, 5) from the ATM switch in the service node **121** to the router in the service node **121**, and 6) from the router in the service node **121** through the metropolitan ATM network **111** and the core ATM network **112** to the Internet **160**. In some embodiments, an Internet Service Provider (ISP) of the Internet **160** is integrated with the ATM network **100** into a single communications network.

Data traffic can flow between any hub and any off-net location. The ATM network **100** transports the data traffic over a PVC between the business **101** and the PSTN **150**, the Internet **160**, or the frame relay network **170**. The PSTN **150**, the Internet **160**, and the frame relay network **170** transport the data traffic and over conventional data connections to the off-net location. The PVC between the business **101** and the PSTN **150** is established: 1) from the business hub **210** in the business **101** through the metropolitan ATM network **110** to the ATM switch **502** in the service node **120**, and 2) from the ATM switch **502** in the service node **120** to the PSTN gateway **508** in the service node **120**. The PSTN gateway **508** is connected to the PSTN **150** over a dedicated TDM link, such as a T1. The PVC between the business **101** and the Internet **160** is established: 1) from the business hub **210** in the business **101** through the metropolitan ATM network **110** to the ATM switch **502** in the service node **120**, 2) from the ATM switch **502** in the service node **120** to the router **506** in the service node **120**, and 3) from the router **506** in the service node **120** through the metropolitan ATM network **110** and the core ATM network **112** to the Internet **160**. The PVC between the business **101** and the frame relay network **170** is established: 1) from the business hub **210** in the business **101** through the metropolitan ATM network **110** to the ATM switch **502** in the service node **120**, 2) from the ATM switch **502** in the service node **120** through the metropolitan ATM network **110** and the core ATM network **112** to the Internet **160**. In some embodiments, a local network, long distance network, ISP, and/or frame relay network is integrated with the ATM network **100** into a single communications network.

From the above-described architecture and traffic flows it can be seen that a typical large business with T1 or greater traffic would interconnect its various sites by ATM PVCs that carry both voice and data between those sites. A typical business site would also be connected by a PVCs to a local telephone network, a long distance telephone network, a frame relay network, and the Internet. All of the PVCs are bundled together into a single ATM connection from the business to the service node in the ATM network. The ATM connection integrates the various communications needs of the business.

Phase II Architecture, Service Node, and Traffic Flows—FIGS. **8–9**

FIG. **8** depicts a Phase II addition to the Phase I architecture. A business **801** is connected to a central office **815**, and the central office **815** is connected to the metropolitan ATM network **110**. The business **801** is similar to the businesses **101–104**, but it is typically smaller. The business **801** includes the CPE **802-803** and the business hub **810**. The CPE **802-803** include telephones, computers, fax machines, LANs and other communications equipment typically found in a business. The business hub **801** is similar to the business hub **210** except that the business hub **810** is equipped with an xDSL/ATM interface for an xDSL/ATM connection between the business hub **810** and the DSL multiplexer **817** in the central office **815**. The business hub **810** exchanges ATM cells that contain voice and data with the DSL multiplexer **817** over the xDSL connection.

The central office **815** is the well known central office in current local telephone networks. The central office **815** includes a Digital Subscriber Line (DSL) multiplexer **817** and an ATM access multiplexer **818**, in addition to numerous other components that are well known in the art, but that are omitted for the purpose of clarity. The DSL multiplexer **817** accepts xDSL/ATM signals from multiple business sites and multiplexes these signals onto a SONET/ATM OC-3 connection to the ATM access multiplexer **818**. One example of the DSL multiplexer **817** is the DSL product provided by Westell. The DSL multiplexer **817** should include redundant OC-3 network interfaces and handle up to **255** telephony connections on the access side and be able to differentiate data from voice. The ATM access multiplexer **818** accepts the SONET/ATM connection from the DSL multiplexer **817** and extends the SONET/ATM connection to the service node **120** over the metropolitan ATM network **110**. The ATM access multiplexer supports Quality-of-Service (QoS) differentiation between voice and data and is includes extensive traffic management features to protect the voice traffic.

FIG. **9** depicts a Phase II addition to the service node **120** of Phase I. The metropolitan ATM network **110**, service node **120**, and PSTN **150** are shown on FIG. **9**. The service node **120** includes the ATM switch **502**, the ISM **504**, the router **506**, and the PSTM gateway **508**. The service node **120** also includes a security server **910** and a remote access server **912**. The remote access server **912** allows dial-up access to CPE in the businesses **801** and **101–104** through the service node **120**. The remote access server supports access by Macintosh, Windows, DOS, or Unix workstations at 56 kilobits/second. The security server provides authentication, authorization, and accounting support to the businesses for mobile users.

The traffic flows for the business **801** are the same as those described for the business **101** except that the business hub **810** in the business **801** is connected to the service node **120** through the DSL multiplexer **817** and ATM access multiplexer **818** in the central office **815** and through the metropolitan ATM network **110**. Traffic flowing between the business **801** and the service node **120** takes this route. The business **801** has ATM PVCs through the service node **120** that are similar to those described above for the business **101**, except that the PVCs for the business **801** flow through the central office **815**. These PVCs typically include PVCs for local telephone traffic, long distance telephone traffic, Internet traffic, dedicated voice traffic, and dedicated data traffic. For example, the PVCs for the local and long distance telephone traffic extend: 1) from the business hub **810** over the DSL connection to the DSL multiplexer **815** and ATM access multiplexer **818** in the central office **815**, 2) from the

ATM access multiplexer **818** through the metropolitan ATM network **110** to the ATM switch **502** in the service node **120**, and 3) from the ATM switch **502** to the PSTN gateway **508** in the service node **120**. The PSTN gateway **508** interworks the ATM and TDM connections and connects to the local and long distance networks using the conventional TDM connections and SS7 links.

Remote Access—FIGS. **1**, **8**, and **9**

Phase II offers remote data access between a remote user and a business, such as the business **101**. The remote user connects to the remote access server **912** in the service node **120** using a modem connection through the PSTN **150**. The remote access server **912** uses a secure IP tunnel to the router **506** in the service node **120** using Layer 2 Tunneling Protocol (L2TP) and In Internet Protocol Security (IP SEC). The router **506** will use an ATM PVC to exchange the traffic with the business hub **210** at the business **101**. The security server **910** handles authentication using the RADIUS protocol. The remote access server **912** and the router **506** mentioned above do not need to be in the same service node. Typically, the remote user will connect to a nearby remote access server using a local telephone call and a 56 kilobit modem. The remote access server will use a secure IP tunnel to a router in another service node that serves the business. The remote access server is typically near the remote user and the router is typically near the business.

Phase III Architecture and Service Node—FIGS. **10–11**

FIG. **10** depicts the Phase III addition to the Phase II architecture. A Work-At-Home (WAH) hub **1010** is connected to the DSL multiplexer **817** in the central office **815** over an xDSL/ATM connection. The business hub **810** is also connected to the DSL multiplexer **817** by an xDSL/ATM connection. The DSL multiplexer **817** is connected to the ATM access multiplexer **818**. The ATM access multiplexer is connected to the service node **120** over the metropolitan ATM network **110**. The business hub **210** is connected to the service node **120** over the metropolitan ATM network **110**. The WAH hub **1010** provides voice and data communications to the business **101** over ATM connections. The primary function of the WAH hub **1010** is to provide an interface for voice and IP over ATM/xDSL. The business hubs **210** and **810** have been upgraded to include provider agents. Provider agents represent software that is able to interact with a session manager in the service node to establish SVC-based communications paths in response to user requests.

FIG. **11** depicts the Phase III addition to the service node **120** with the ATM switch **502**, ISM server **504**, router **506**, PSTN gateway **508**, security server **910**, and remote access server **912**. An intranet server **1114**, session manager **1116**, feature server **1118**, Dynamic Host Configuration Protocol (DHCP) and Domain Name Service (DNS) server **1120**, and IP forwarder **1122** are added and connected to the ATM switch **502**. The ATM switch **502** must support Switched Virtual Circuits (SVCs) in Phase III. The intranet server **114** provides intranets for the businesses. The intranet server **114** can be accessed through the various hubs or through a secure modem connection to a remote access server. The feature server **1118** provides various features such as, class **5** switch features, voice mail, call forwarding, call waiting, call transfer, internet web browsers, and software downloading. The feature server **1118** is TINA-C compliant. The DHCP/DNS server **1120** provides auto-configuration of IP-aware devices. It dynamically synchronizes domain name databases and dynamically assigns IP addresses. The IP forwarder **1122** provides IP routing and forwarding for data traffic. The IP forwarder **1122** performs aggregation of IP PVCs from the businesses for the router **506**. The IP router **506** supports priority levels and is compliant with ATM forum User to Network Interface (UNI) **3.1** recommendations.

The session manager **1116** controls the set-up and delivery of communications services. The session manager **1116** interacts with the provider agents in the various hubs to establish connections using SVCs in response to user requests. The session manager **1116** is compliant with the Telecommunication Information Network Architecture Consortium (TINA-C). Version 8.0 of the "Retailer Reference Point Specification" issued by TINA-C specifies the session manager **1116**, the connections between the session manager **1116** and the provider agents, and the messages exchanged between the session manager **1116** and the provider agents. The interface between the session manager **1116** and the provider agents is defined by the Retailer Reference Point Specification in Object Definition Language (ODL) and is compiled into the Interface Definition Language (IDL) of the Common Object Request Broker Architecture (CORBA) and is transported over ATM using classic IP.

The PSTN gateway **508** is upgraded in Phase III to support the SS7 signaling and session manager **1116** call routing. A version of the provider agent is resident in the PSTN gateway **508** to interface between the session manager **1116** and the PSTN **150**. The PSIN gateway **508** is connected to local networks over a TR-395 connection with associated SS7 signaling links. The PSTN gateway **508** is connected to long distance networks over a TR-317 connection with associated SS7 signaling links. The PSTN gateway **508** interworks the TDM traffic from the PSTN **150** with the ATM traffic from ATM switch **502**. The PSTN gateway **508** also interworks SS7 ISUP/TCAP signaling and ISDN signaling from the PSTN **150** with ATM signaling from session manager **1116**. The PSFN gateway **508** supports intelligent network functions such as **800**, LIDB, local number portability, E911, and operator services. The PSTN gateway **508** utilizes AAL1 based DS0 circuit emulation with echo cancellation.

Provider Agents and Hubs—FIGS. **12–14**

FIG. **12** depicts a provider agent **1200** that is coupled to an Application Programming Interface (API) **1202**. The API **1202** is coupled to a hub **1204**. The hub **1204** is connected to phones **1205–1206** over channels A and B respectively. The provider agent **1200** is coupled with the session manager **1116** in the service node **120**. The hub **1204** is connected to the ATM switch **502** in the service node **120**. There may be equipment coupled in between the hub **1204** and the phones **1205–1206**, such as the PBX **304**, and there may be equipment coupled in between the hub **1204** and the ATM switch **502**, such as the DSL multiplexer **817** and the metropolitan ATM network **111**, but the equipment is not depicted on FIG. **12** for the sake of clarity.

The hub **1204** represents a generic version of the business hubs **210** and **810**, the WAH hub **1010**, the residential hub **1900**, the analog hub **1902**, or the PSTN gateway **508**. In various embodiments of the invention, the hub **1204** interacts with PSTN **150**, the PBX **302**, or the channel bank **303**. In other embodiments of the invention, the hub **1204** interacts directly with the phones **1205–1206**. The latter embodiment of the hub **1204** is discussed below, but those skilled in the art will recognize how the teachings could be applied to a provider agent and hub in operational combination with the PSTN **150**, the PBX **302**, or other similar equipment.

In some embodiments, the channels in the hub **1204** to the phones **1205–1206** are conventional telephone ports. The hub **1204** includes circuitry to interwork analog telephony

signals from the phones **1205–1206** with the digital signals to the service node **120**. The hub **1204** includes circuitry that generates dial tones, ring-back tones, busy tones, fast-busy tones, and ring current for the phones **1205–1206**. The hub **1204** includes circuitry that detects Dual Tone Multi-Frequency (DTMF) digit events, off-hook events, and on-hook events, and that provides messages indicating these events. The hub **1204** includes software control systems that control the circuitry and interface with the API **1202**.

The phones **1205–1206** represent any communications devices supported by the hub **1204**. Some examples are conventional analog telephones, wireless phones, computers, modems, and fax machines. Additional phones could be connected to channels A and B, or additional phones could be connected to additional channels on the hub **1204**. Only two channels with one phone each is shown for the sake of clarity.

The API **1202** is a software interface that exchanges event messages and instructions between the hub **1204** and the provider agent **1200**. The provider agent **1200** accepts event messages from the hub **1204** through the API **1202** and provides instructions back to the hub **1204**. For example, the provider agent **1200** might receive information through the API **1202** that the phone **1205** has gone off-hook. In response, the provider agent **1200** might provide a control instruction through the API **1202** to the hub **1204** to provide dial tone to the phone **1205**. In some embodiments of the invention, the API **1202** is specified in the Information Definition Language (IDL) of the Common Object Request Broker Architecture (CORBA).

The provider agent **1200** responds to event messages for the phones **1205–1206** with instructions for the hub **1204** to interact with the user. User interaction includes dial tone, digit collection, ring, ringback, and busy signals. The provider agent **1200** also exchanges messaging with the session manager **1116**. Messages include invite messages, reply messages, join messages, and terminate messages.

Both the provider agent **1200** and the API **1202** are comprised of software that is stored on a software storage medium. Examples of a software storage medium include magnetic disks, optical disks, or integrated circuits. The provider agent **1200** and the API **1202** could also be stored on a server and down-loaded to a user over the Internet **160** or another operational connection. In some embodiments of the invention, the provider agent is comprised of objects written in C++code.

FIG. **13** depicts one example of a software architecture for the provider agent **1200**. The provider agent **1200**, the API **1202**, the hub **1204**, the phones **1205–1206**, and session manager **1116** operate as discussed above. The provider agent **1200** is comprised of the following software objects: a controller object **1300**, port objects **1301–1302**, event objects **1303–1304**, and a thread manager object **1305**. The port object **1301** and the event object **1303** are associated with channel A. The port object **1302** and the event object **1304** are associated with channel B. The software objects **1300–1305** are executed by a multi-threaded processing system with each object having its own thread. Each object also has a queue that is indicated on FIG. **13** by the letter "Q". The queue is the software component that receives and buffers messages for the object.

The controller object **1300** communicates with the session manager **1116** and the port objects **1301–1302**. Communications with the session manager **1116** are comprised of the following messages:

Start Service—a message to the session manager that initially identifies the service requested and includes an access key, a service ID, and user information.

Reference Information—a message from the session manager that includes session ID, party ID, and a secret ID.

Invite—a message that requests a telephony session and includes the dialed number(s).

Reply—a message that responds to an Invite message and indicates alerting, busy, or reject.

Join—a message that indicates that the party is ready to join the session.

Add Stream—a message to the session manager that requests a connection to be established to another party and that includes the terminal ID, the Party ID and the Virtual Path (VP)/Virtual Connection (VC).

Join Stream—a message from the session manager that requests a party to attach to a connection from another party.

Terminate—a message that is sent or received by the provider agent and that indicates that the session is over.

The controller object **1300** encapsulates call related information by generating call record objects that are identified by session ID and channel ID. The controller object **1300** stores data indicating the idle or busy status of each channel. The controller object **1300** includes an internal data structure for any desired call-handling policies. Call handling policies include rules for call waiting, voice mail, call blocking, and the internal routing of incoming calls to particular phones, such as idle phones. These policies can be varied based on the caller's number, the time of day, or other factors.

The port objects **1301–1302** are state machines. FIG. **14** depicts one example of a state machine for the port object **1301** in block diagram form. The initial state is Idle. An off-hook event for channel A moves the port object **1301** to the dial tone state and an instruction to provide dial tone is provided to the hub **1204**. A digits event for channel A moves the port object **1301** to the collect digits state and an instruction to stop dial tone is provided to the hub **1204**. The port object **1301** creates a digit collection object. Digits that are collected by the hub **1204** are provided to the digit collection object for analysis. The digit collection object determines the type of number dialed, such as emergency numbers, seven-digit numbers, ten-digit numbers, and international numbers. The digit collection object instructs the port object **1301** when digit collection is complete. A digits complete event for channel A moves the port object **1301** to the call proceeding state and the port object **1301** instructs the controller object **1300** to send Start Service and Invite messages to the session manager **1116**. An alerting indication from the controller object **1300** moves the port object **1301** to the ringback state where a ringback instruction is provided to the hub **1204**. The alerting event is based on a reply message from the session manager **1116**. A join event from the controller object **1300** moves the port object **1301** to the active state where the session is conducted. The join event is based on a join message from the session manager **1116**. An on-hook event for channel A moves the port object **1301** back to the idle state and results in a termination message being sent by the controller object **1300** to the session manager **1116**.

A few deviations from the above-described state machine should be appreciated. If the reply message had a busy indication, a busy state would be entered instead of the ringback state, and a busy tone instruction would be provided to the hub **1204**. If the reply message had a reject indication, a fast-busy state would be entered instead of the ringback state and a fast-busy tone instruction would be provided to the hub **1204**. In both of the above cases, an on-hook event moves the port object **1301** back to the idle state.

When receiving a call, the state machine is much simpler. In the idle state, an invite indication from the controller object **1300** moves the port object **1301** to the ring state where the hub **1204** is instructed to ring channel A. The invite indication is based on an invite message from the session manager **1116**. An off-hook event for channel A moves the port object **1301** to that active state, until an on-hook event moves the port object **1301** back to the idle state.

Referring back to FIG. **13**, the event objects **1303–1304** track the events for each respective channel and indicate the events to the respective port objects **1301–1302**. The event object **1303** can process events using a different thread than the port object **1301**, and the event it object **204** can process events using a different thread than the port object **202**. Multi-threaded processing in this manner has advantages. Multi-threading simplifies system design and is more efficient than a single-threaded system. Multi-threading allows multiple threads to be processed in various states at the same time without the entire system waiting for a single input. Multi-threading also simplifies race conditions to single channel events.

The API **1202** utilizes a messaging format comprised of an instruction followed by variables in parentheses. The primary instructions are:

start ring (channel ID)

stop ring (channel ID)

start tone (channel ID, tone type)

stop tone (channel ID, tone type)

wait event (channel ID, event type)

event (channel ID, event type, value)

open voice channel (channel ID, VPI/VCI)

close voice channel (channel ID, VPI/VCI)

In the above messages, the channel ID identifies the relevant channel of the hub **1204**. The tone types are dial tone, ringback, busy, and fast-busy. The event types are off-hook, on-hook, and digit. The value is the value of the digit. The VPI/VCI identifies the Virtual Path and Virtual Channel used by the hub **1204** for the session.

The thread manager object **1305** provides fault tolerance for software failures and certain hardware failures. The thread manager object **1305** continuously receives heartbeat messages from the objects **1300–1304**. If a heartbeat message is not received as expected, the thread manager object **1305** identifies and attempts to restart the affected thread. If the heartbeat is still absent, the thread manager object **1305** instructs the hub **1204** to use conventional fail-over analog telephone service for the channel with the malfunctioning thread.

Hub, Provider Agent, Session Manager Interaction—FIGS. **15–17**

FIGS. **15–17** depict a message sequence chart for some operative examples of the invention. In the first example starting on FIG. **15**, the port object **1301** sends "wait event (A, off-hook)" to the hub **1204**. When the user places a call by taking the phone **1205** off-hook, the hub **1204** detects the off-hook event and transmits "event (A, off-hook)" to the event object **1303**. Messages between the hub **1204** and the event object **1303** or the port object **1301** utilize the API **1202**. The event object **1303** provides an off-hook indication to the port object **1301**. The port object **1301** moves from the idle state to the dial tone state and responds to the hub **1204** with the messages "start tone (A, dial)" and "wait event (A, digit collection)". The port object **1301** also generates an instance of a digit collection object to process subsequently collected digits.

The user inputs a called number using the telephone **1205**. The hub **1204** detects the digits and forwards the values to the event object **1303** with messages such as "event (A, digit, 1)" and "event (A, digit, 8)". The event object **1303** provides a digit indication to the port object **1301**. After the first digit, the port object **1301** moves from the dial tone state to the digits state and sends "stop tone (A, dial)" to the hub **1204**. In response, the hub **1204** stops the dial tone on channel A. The port object **1301** also processes the digit values with the digit collection object.

The digit collection object determines that the formatting of the called number is correct and that digit collection is complete. The digit collection object indicates to the port object **1301** that digit collection is complete and provides the called number. In response to the digits complete message, the port object **1301** moves from the digits state to the call proceeding state and indicates a request for telephony service with the dialed number to the controller object **1300**.

The controller object **1300** generates and transmits a Start Service message requesting telephone service to the session manager **1116**. The session manager responds with reference information such as the session ID, the party ID, and a secret ID. On FIG. **16**, the controller object **1300** generates and transmits an invite message with the dialed number to the session manager **1116**. The session manager **1116** typically sets-up the session and returns a reply message to the controller object **1300** indicating that the called party is being alerted. Alternatively, the called party might be busy or might reject the session.

If an alerting indication is received in the reply message, the controller object **1300** indicates the alerting condition to the port object **1301**, and the port object moves to the ringback state. The port object **1301** sends "start tone (A, ringback) to the hub **1204**. In response, the hub **1204** puts a ringback tone on channel A to emulate a ringing phone at the far end.

When the party at the far end accepts the invitation, a Join message is sent back to the controller object **1300**. The controller object **1300** indicates the join condition to the port object **1301** and identifies the VPI/VCI for the session. The controller object **1300** also generates and transmits an add stream message to the session manager **1116** with the terminal ID, the party ID, and the VPI/VCI. The port object **1301** sends "open voice channel (A,VPI/VCI)" to the hub **1204**. In response to the open voice channel message, the hub **1204** stops the ringback tone and interworks the analog telephony signal on channel A with the ATM signal on the VPI/VCI. At this point, the session is in progress and the telephone call can proceed.

The session ends when the user places the phone **1205** on-hook. The hub **1204** sends "event (A, on-hook)" to the event object **203** which indicates the on-hook to the port object **1301**. The port object **1301** indicates the termination status to the controller object **1300** and sends "close voice channel (A, VPI/VCI)" to the hub **1204**. The hub **1204** ceases to interwork channel A with the VPI/VCI. The controller object **1300** generates and transmits a Terminate message to the session manager **1116**.

FIG. **17** depicts a call to the phone **1205** that is terminated by the other party. The controller object **1300** first receives an Invite message with a session ID and dialed number from the session manager **1116**. The controller object **1300**, based on its call-handling policy, determines which phone to route the call to. In some cases, the dialed number is used to select the appropriate phone. In this example, the call is routed to channel A. The controller object **1300** indicates the invitation to the port object **1301**, and the port object **1301** sends

"start ring (A)" to the hub **1204**. The hub **1204** begins to ring the phone **1205**. The controller object **1300** sends a reply message back to the session manager **1116** indicating that the user is being alerted. In the alternative, the reply message sent to the session manager **1116** could indicate that the phone **1205** was busy or that the session was rejected.

When the user takes the phone **1205** off-hook to answer the call, the hub **1204** sends "event (A, off-hook)" to the event object **1303** which indicates the off-hook to the port object **1301**. The port object **1301** sends "stop ring (A)" the hub **1204** which stops the ringing. The port object **1301** informs the controller object **1300** that the user has joined the session and the controller object **1300** sends a join message to the session manager **1116**. The controller object **1300** receives reference information from the session manager **1116** indicating the session ID, party ID, and secret ID. The controller object **1300** also receives a join stream message from the session manager **1116**. The controller object sends a join stream indication to the port object **1301** identifying the VPI/VCI for the session. The port object **1301** sends "open voice channel (A,VPI/VCI)" to the hub **1204**. At this point, the session manager **1116** has the information to set-up the connection. Subsequently, the session is in progress and the telephone call can proceed.

The session ends when a termination message is received by the controller object **1300** from the session manager **1116**. The controller object **1300** indicates the termination status to the port object **1301** which sends "close voice channel (A, VPI/VCI)" to the hub **1204**. The hub **1204** ceases to interwork channel A with the VPI/VCI.

It should be appreciated that various combinations of call origination and termination can occur in the context of the invention. For example the phone **1205** can originate a call or receive a call. Likewise, the phone **1205** can terminate a call or the called party can terminate a call. It should also be appreciated that the port object **1302** and the event object **1304** operate in a similar fashion to the port object **1301** and the event object **1303** respectively. Using these objects, the provider agent can handle multiple sessions at the same time. A provider agent can have numerous such objects, but only two groups are shown for purposes of clarity.

Race conditions exist when improper events occur given the current state of the port objects **1301–1302**. This typically occurs when calls are incoming and outgoing at the same moment. One example is where an invite message is received by the controller object **1300**, and the controller object **1300** determines that the status of channel A is idle, but in reality, the port object **1301** is already in the dial tone state due to an off-hook event. The port object **1301** will receive an invite indication from the controller object **1300** when it expects to receive digit indications from the event object **1303**. In this case, the port object **1301** must instruct the controller object **1300** to reply busy or reject, and to set channel A status to busy.

In another example, the controller object **1300** may receive an invite message from the session manger **161**, but before the phone **1205** rings, the phone **1205** goes off-hook. The port object **1301** will receive an invite indication from the controller object **1300** and an off-hook event from the hub **1204**. In this case, the port object **1301** instructs the hub **1204** to open the voice channel and VPI/VCI for the incoming call as if the phone was answered for that call.

The Work-at-Home Hub—FIG. **18**

FIG. **18** depicts an example of the WAH hub **1010** in some embodiments of the invention. Conventional requirements for the WAH hub **1010** can be found in Telecommunications Industry Association (T1A) document SP-3771. Shown is the WAH hub **1010** and it includes an ADSL/ATM interface **1800** and an ATM backplane **1802**. Together, these components allow for ATM communications within the hub **1010** and with external elements through the ADSL/ATM interface **1800**. The ADSL/ATM interface **1800** converts end user control and communications into the ADSL/ATM format for transport to the service node **120**. The provider agent **1200** and the session manager **1116** communicate through the ATM/ADSL interface **1800**. The ATM/ADSL interface **1800** also receives communications and control from the network and provides these to the appropriate components of the hub **1010**. The ADSL/ATM **1800** interface also provides smoothing and shaping for the ATM signals.

Several cards can be connected to ATM backplane **1802**. In this example, a LAN card **1804** and a telephony card **1806** are shown. The cards can communicate with each other through s the ATM backplane **1802** and with the service node **120** through interface **1800**. An un-interruptable power supply (UPS) may be included if desired in order to provide power during an outage to the home. The LAN card **1804** supports an ethernet connection to a computer. The computer could access the LAN **301** at the business **101** using IP over ATM through the ADSL/ATM interface **1800**. The computer could also access the servers and routers in the service node **120** for additional services.

The telephony card **1806** supports analog telephony communications with the telephones. The telephony card **1806** is controlled by a provider agent that is resident in the hub **1010**. The telephony card **1806** provides dial tone and power to the telephones. The telephony card **1806** can detect on-hook and off-hook conditions as well as DTMF tones. The telephony card **1806** I; can provide ringback and busy tones to the telephones. The telephony card **1806** can also provide analog to digital conversion In some embodiments, the telephony card **1806** provides echo cancellation or other digital signal processing functions. The provider agent for the telephony card **1806** exchanges control information (i.e. dialed number) with the session manager **1116** through ADSL/ATM interface **1800**. One example of telephony card **1806** is provided by InnoMedia Logic (IML) of Quebec.

There are various connection options between the hub **1204** and the service node **120**. ATM connections could be provisioned as PVP/PVCs from the hub **1204** directly to the service node **120**. This tends to waste bandwidth in the metropolitan ATM network **111**. Where the DSL multiplexer **817** is used, ATM connections could be provisioned from the hub **1204** to the multiplexer **817**, and SVCs could be used between the multiplexer **817** and the service node **120**. The entire connection between the hub **1204** and the service node **120** could establish SVCs as needed. In addition, combinations of the above could be provided. For example, low bandwidth control channels could be provisioned directly from the hub **1204** to the service node **120**, but higher bandwidth bearer channels could be established on an SVC basis.

The traffic flows in Phase III can be the same as discussed above for Phases I and II, but traffic flows can also be determined by the session manager **11 16** and the provider agents. For example, the business may retain some dedicated PVC-based connections, and may replace some PVC-based connections with SVC capability using provider agents and the session manager. The use of SVCs is typically more efficient than the use of PVCs. When a user at the business **101** requests a communications service, the provider agent in the business hub **210** interacts with the session manager **1116** in the service node **120** to set-up the appropriate SVCs from the business hub **210** to the appropriate termination

point of network **100**. For on-net to on-net calls, an SVC would be established between the relevant hubs through the interaction of the session manager and the provider agents in the relevant hubs. The provider agents would also direct the conventional telephony operations for each respective telephone. For example, the provider agent may direct a PBX to complete the call or may direct a telephone to provide dial tone. For calls that either originate or terminate off-net, and SVC would be established from the business hub **210** to the PSTN gateway near the off-net party through the interaction of the session manager **1116** and the provider agents in the relevant hub and PSTN gateway. The provider agents would also direct the conventional telephony operations for each respective telephone. For example, the provider agent in the hub may direct a PBX to complete the call or may direct a telephone to ring, and the provider agent in the PSTN gateway may send or receive an SS7 Initial Address Message to the PSTN **150**. The PSTN **150** would be used to originate or terminate the call to the off-net party.

The session manager **1116** and provider agents could also be used to establish data connections. On-net to on-net data connections might connect two ethernet LANs by an SVC to exchange data between computers. The hubs would interwork the ethernet LAN connection with the ATM SVC through the network. For off-net data, an SVC would be established from the relevant hub to: 1) the PSTN gateway to exchange data with the PSTN **150**, 2) the service node router to exchange data with the Internet **160**, or 3) the frame relay network **170** If the Internet site is on-net, the session manager **1116** will set-up an ATM SVC from the relevant hub to the hub or service node for the Internet site. For example, if a web site is in a server at the business **104**, and a user at the business **101** seeks access to the web site, then the session manager **1116** would establish an SVC between the businesses **101** and **104**. The Internet session would not need to access the Internet **160**, but would be facilitated by the ATM network **100**. The customers of the network **100** would have private, high-speed, SVC-based access to web servers that are on-net.

Phase IV Architecture—FIG. **19**

FIG. **19** depicts a Phase IV architecture. The following elements shown on FIG. **19** operate and are connected as described above: metropolitan ATM networks **110–111**, core ATM network **112**, service node **120**, PSTN **150**, Internet **170**, frame relay network **170**, business hub **210**, business hub **810**, central office **815**, DSL multiplexer **817**, ATM access multiplexer **818**, and the WAH hub **1010**. A residential hub **1900** and an analog hub **1902** that are representative of the hub **1204** have been added for Phase IV.

The residential hub **1900** is connected to a telephone **1901** at the residence. The residential hub **1900** is connected to the DSL multiplexer **817** in the central office **815** by an xDSL/ATM connection for access to the service node **120** through the ATM access multiplexer **818** and the metropolitan ATM network **110**. The residential hub **1900** houses a provider agent and an ATM interface to serve the communications needs of the residence through the service node **120**. Such services might include telephone calls, Internet **170** access, e-mail, and video, among others.

The analog hub **1902** is connected to the service node through the metropolitan ATM network **110**. The analog hub **1902** is connected to multiple telephones **1903–1904** over conventional analog or Digital Loop Carrier (DLC) lines. The analog hub **1902** is also connected to a local network in the PSTN **150** by GR-303 connections. The analog hub **1902** provides conventional telephone service to customers who do not have residential hubs. The analog hub **1902** interworks between the conventional telephone format and the ATM format, and includes a provider agent that interacts with the session manager **1116** in the service node **120**.

The Residential Hub—FIG. **20**

FIG. **20** depicts an example of the residential hub **1900** in some embodiments of the invention. Conventional requirements for the residential hub **1900** can be found in Telecommunications Industry Association (TIA) document SP-3771. The residential hub **1900** includes the ADSL/ATM interface **1800**, the ATM backplane **1802**, the LAN card **1804** and the telephony card **1806** from the WAH hub **1010**. The residential hub **1900** could be adapted from the WAH hub **1010**. The residential hub **1600** also includes a Java card, ATM card, MPEG card, and utility card that are connected to the ATM backplane **1802**.

The ATM backplane **1802** is connected to the xDSL/ATM interface **1800** and these components allow for ATM communications within the hub **1900** and with external elements through xDSL/ATM interface **1800**. The xDSL/ATM interface **1800** converts end user control and communications into the xDSL/ATM format for transport to the service node **120**. The xDSL/ATM interface **1800** also receives communications and control from the service node **120** and provides the communications and control to the appropriate components of hub **1900**. ADSL/ATM interface **1800** also provides smoothing and shaping for the ATM signals. The various cards can communicate with each other through the ATM backplane **1802**. The cards can also communicate with the service node **120** through interface **1800**. An un-interruptable power supply (UPS) may be included if desired in order to provide power during an outage to the residence.

The Java card **2002** includes a processor and memory and is operational to receive Java applets from the service node **120**. Java applets can support a wide variety of tasks. In particular, Java applets can be used to provide the intelligence to support class **5** switch features for telephone service, such as call waiting and call forwarding. Java card **2002** also exerts control over the other cards and the xDSL/ATM interface **1800**. This could include ATM virtual connection assignments for communications to the DSL multiplexer **817** or the service node **120**. Java card **2002** may also communicate with the service node **120** to request numerous other communications services. The ATM card **2004** provides an ATM interface to devices within the residence. If the ATM card **2004** exchanges ATM signaling with resident devices over VPI=0 and VPI=5, then ATM card **2004** may use virtual path associated signaling to exchange control information with the service node **120**. The MPEG card **2006** provides an MPEG interface to devices within the residence. MPEG is a video formatting standard provided by the Motion Picture Entertainment Group (MPEG). Typically, the MPEG card **2006** will receive MPEG formatted video in ATM cells through xDSL/ATM interface **1800** and provide video signals to devices in the residence. Utility card **2008** is coupled to utility metering devices in the residence. The utility card **2008** is programmed to collect the metering information and forward it to the utility companies through xDSL/ATM interface **1800**. The LAN card **1804** supports a LAN that is internal to the residence. For example, LAN card **1804** could support ethernet connections to multiple computers. The computers could access the Internet **170** through the LAN card **1804** and the xDSL/ATM interface **1800**.

The telephony card **1806** supports analog telephony communications with the telephone **1901** in the residence. Other telephones could also be supported but are not depicted for

clarity. The telephony card **1806** is controlled by a provider agent that is resident in the residential hub **1900**. The telephony card **1806** provides dial tone and power to the telephone **1901**. The telephony card **1806** can detect on-hook and off-hook conditions as well as DTMF tones. The telephony card **1806** can provide ringback and busy tones to the telephone **1901**. The telephony card **1806** can also provide analog to digital conversion In some embodiments, the telephony card **1806** provides echo cancellation or other digital signal processing functions. The provider agent for the telephony card **1806** exchanges control information (i.e. dialed number) with the session manager **1116** in the service node **120** through the xDSL/ATM interface **1800** or through the Java card **2002** and the xDSL/ATM interface **1800**. One example of the telephony card **1806** is provided by InnoMedia Logic (IML) of Quebec.

The Analog Hub—FIG. **21**

FIG. **21** depicts a version of the analog hub **1902**. Shown are telephones **1903–1904**, the DSL multiplexer **817** in the central office **815**, the ATM switch **502** in the service node **120**, and local networks within the PSTN **150**. The metropolitan ATM network **111** is omitted for clarity. These components are connected as described with respect to FIG. **19**. The analog hub **1902** is shown connected to only two phones **1903–1904** for reasons of clarity, but the analog hub **1902** is typically connected to approximately 200 phones on 200 channels.

The analog hub **1902** is comprised of connection element **2104** and control element **2105**. Connection element **2104** comprised of a telephony interface, a digital signal processor (DSP), a central processing unit (CPU), an ATM interface, and an ATM backplane. The telephony interface provides an interface with DSL multiplexer **817**, telephones **1903** and **1904**, and the PSTN **150** over conventional telephony connections such as local loops, DLC signals, DS1 connections, and DS3 connections. The DSP provides echo cancellation and modem emulation. Other DSP functions could also be implemented. The CPU provides control. The ATM interface provides an interface to the ATM switch **502**. The ATM backplane allows these elements to communicate and interact.

Control element **2105** is comprised of a Signaling System #7 interface, a CPU, and an ATM interface. The SS7 interface provides an interface with the SS7 components in the PSTN **150** over SS7 links. The CPU provides control and houses a provider agent for the telephone channels on the telephony interface. The ATM interface provides an interface to the ATM switch **502**. Control element **2105** could be configured as a programmed Unix-based computer. Connection element **2104** and control element **2105** could be integrated onto a single platform, and the analog hub **1902** could be adapted from the LDR-2000 provided by Yurie Systems.

In operation the analog hub **1902** can support conventional telephony for telephones **1903–1904** using AAL1 based DS0 circuit emulation. The analog hub **1902** also would provide power, dial tone, digit collection, ring back, busy tone, and ringing. For outbound calls, the dialed digits would be forwarded to the provider agent in the CPU of the control element **2105**. A call request message containing the dialed digits is generated by the provider agent and is converted to ATM by the control element **2105** and provided to the session manager **1116** in the service node **120** through the ATM switch **502**. The provider agent in the control element **2105** would receive instructions from the session manager **1116** in the service node **120** through ATM switch **502** and exert control over the connection element **2104**. The connection element **2104** would interwork the telephony signals from the telephones **1903–1904** with the appropriate ATM virtual connection to ATM switch **502** or to the PSTN **150** as appropriate. For inbound calls, the provider agent in the control element **2105** would receive an instruction from the session manager **1116** in the service node **120** through the ATM switch **502** to for a call to a particular telephone number. The provider agent would instruct the connection element **2104** to ring the telephone associated with that telephone number. Once the call is answered, connection element **2104** would interwork the telephony from the telephone with the appropriate ATM virtual connection to ATM switch **502** or to the PSTN **150** as appropriate. The analog hub **1902** uses conventional connections and SS7 signaling to transfer calls to and from the PSTN **150**.

Phase IV Operation—FIG. **19**

To illustrate the operation of the Phase IV architecture depicted in FIG. **19**, a few examples will be discussed. One skilled in the art will appreciate that numerous other examples could also be supported by the invention. In the first example, the telephone **1904** is used to call the telephone **1901**. A user takes the telephone **1904** off-hook. The analog hub **1902** senses the off-hook, and under control of the provider agent, provides dial tone to the telephone **1904**. The user inputs the called number digits and the analog hub **1902** detects the digits. When the digits are collected, the provider agent in the analog hub **1902** requests a communications path for the call from the session manager **1116** in the service node **120**.

The session manager **1116** in the service node **120** processes the called number and identifies the residential hub **1900** as the network termination point. The session manager **1116** instructs the provider agent in the residential hub **1900** to alert the telephone **1901**, and the telephony card **1806** in the residential hub **1900** rings telephone **1901**. The provider agent in the residential hub **1900** sends a reply through the session manager **1116** to the analog hub **1902** indicating that telephone **1901** is ringing. The provider agent in the analog hub **1902** causes the analog hub **1902** to play a ringback tone to telephone **1904** to emulate the ringing telephone for the caller. If the telephone **1901** had been busy, the reply would have indicated a busy status and the provider agent in the analog hub **1902** would have caused the analog hub **1902** to play a busy tone to the telephone **1904**.

The session manager **1116** sends a control message to the ATM switch **502** in service node **120** to establish an SVC from the analog hub **1902** to the residential hub **1900** through the metropolitan ATM network **111** and the multiplexers **817–818**. The connections between the residential hub **1900** and the telephone **1901** and between the analog hub **1902** and the telephone **1904** are conventional telephone connections.

If the telephone **1901** is answered, the telephony card **1806** in the residential hub **1900** detects the off-hook condition and the provider agent in the residential hub **1900** sends a message through the session manager **1116** to the provider agent in the analog hub **1902** that the called party has joined the call. The provider agent in the residential hub **1900** directs the telephony card **1806** to interwork the ATM connection with the conventional telephony connection to the telephone **1901**. The provider agent in the analog hub **1902** directs the analog hub **1902** to interwork the ATM connection with the conventional telephony connection to the telephone **1904**. At this point, the call connection is established. When either telephone **1901** or **1904** hangs up, the respective hub **1900** or **1902** will detect the on-hook

condition and the associated provider agent will send a termination message through the session manager **1116** to the other provider agent. As a result, the ATM connections and the connections to the telephones **1901** and **1904** are released.

The above example represents an on-net call. Other on-net calls could be handled in a similar fashion for any telephones that are connected to a business hub, WAH hub, residential hub, or analog hub. The SVCs for the calls can be set-up in between these hubs through the metropolitan ATM networks **110–111** and the core ATM network **112**. Advantageously, the ATM fabric that is used to provide Internet, video, and data communications is also used to provide conventional telephone service—even to users who only have conventional telephones and desire only standard telephone service.

In the next example, the telephone **1901** is used for an off-net call to a telephone **1905** that is connected to the PSTN **150**. A user takes the telephone **1901** off-hook. The telephony card **1806** in the residential hub **1900** senses the off-hook, and under control of the provider agent, provides dial tone to the telephone **1901**. The user inputs the called number digits and the telephony card **1806** detects the digits. When the digits are collected, the provider agent requests a communications path for the call from the session manager **1116** in the service node **120**.

The session manager **1116** in the service node **120** processes the called number and identifies the PSTN gateway **508** as the network termination point. The session manager **1116** instructs the provider agent in the PSTN gateway **508** to alert the telephone **1905**, and the PSTN gateway **508** sends an SS7 IAM that includes the dialed number to the PSTN **150**. The PSTN **150** rings the telephone. **1905** and responds to the PSTN gateway **508** with an SS7 Address Complete Message (ACM) with an alerting indication. The provider agent in the PSTN gateway **508** sends a reply through the session manager **1116** to the residential hub **1900** indicating that telephone **1905** is ringing. The provider agent in the residential hub **1900** causes the telephony card **1806** to play a ringback tone to telephone **1901** to emulate the ringing telephone for the caller. If the telephone **1905** had been busy, the ACM from the PSTN **150** and the reply from the PSTN gateway **508** would have indicated a busy status, and the provider agent in the residential hub **1900** would have caused the telephony card **1806** to play a busy tone to the telephone **1901**.

The session manager **1116** sends a control message to the ATM switch **502** in service node **120** to establish an SVC from the residential hub **1900** to the PSTN gateway **508** through the metropolitan ATM network **111** and the multiplexers **817–818**. The connections between the residential hub **1900** and the telephone **1901** and between the PSTN gateway **508** and the telephone **1905** are conventional telephone connections.

If the telephone **1905** is answered, the PSTN **150** detects the off-hook condition and sends an SS7 Answer Message (ANM) to the PSTN gateway **508**. The provider agent in the PSTN gateway **508** sends a message through the session manager **1116** to the provider agent in the residential hub **1900** that the called party has joined the call. The provider agent in the PSTN gateway instructs the PSTN gateway **508** to interwork the ATM connection with the conventional telephony connection to the telephone **1905**. The provider agent in the residential hub **1900** directs the telephony card **1806** to interwork the ATM connection with the conventional telephony connection to the telephone **1901**. At this point, the call connection is established. When either telephone **1901** or **1905** hangs up, the residential hub **1900** or the PSTN **150** will detect the on-hook condition and the associated provider agent will send a termination message through the session manager **1116** to the other provider agent. As a result, the ATM connections and the connections to the telephones **1901** and **1904** are released.

The above example represents an off-net call. Other off-net calls could be handled in a similar fashion to or from for any telephones that are connected to the PSTN **150**. The SVCs for the calls can be set-up in between any hub and any PSTN gateway through the metropolitan ATM networks **110–111** and the core ATM network **110**. Advantageously, the ATM fabric that is used to provide Internet, video, and data communications is also used to provide conventional telephone service—even to users who only have conventional telephones and desire only standard telephone service.

The residential hub **1900** may be required to handle an emergency **911** call from the telephone **1901**. Typically, the call is handled as indicated above, but if systems are down or the power to the residential hub **1900** has failed, the residential hub **1900** and the DSL multiplexer **817** can be adapted to automatically connect the affected local loop to the analog hub **1902**. The analog hub **1902** can then power the phone **1901** and provide conventional telephone service to the telephone **1901**.

An important feature of the provider agents, the residential hub **1900**, and the analog hub **1902** is the support of POTS service by providing a proxy. The telephones operate in their normal manner, and the agents and hubs provide an "interpreter" between the telephones and the session manager **1116**. This "interpreter" function is a proxy. A proxy could also be provided for legacy Internet communications. When a computer at a residence attempted an Internet communication, the proxy would intercept the IP packet. The proxy could either translate the IP address into a destination and provide the destination to the session manager **1116**, or simply forward the IP address the session manager **1116**. Either way, the session manager would set up an ATM SVC to the destination if the destination is on-net. If the destination is off-net, an SVC to the appropriate on-net router would be used for subsequent Internet access. The legacy application on the computer could communicate using IP addressing, but would be supplied with ATM connections using the proxy.

Those skilled in the art can appreciate variations of the above-described embodiments that fall within the scope of the invention. As a result, the invention is not limited to the specific embodiments discussed above, but only by the following claims and their equivalents.

What is claimed is:

1. A communications network that comprises:

a first metropolitan Asynchronous Transfer Mode (ATM) network;

a first business hub that is connected to the first metropolitan ATM network;

a second business hub that is connected to the first metropolitan ATM network;

a Public Switched Telephone Network (PSTN) gateway that is connected to the first ATM metropolitan network;

a first ATM Permanent Virtual Connection (PVC) from the first business hub to the second business hub through the first metropolitan ATM network;

a second ATM PVC from the first business hub to the PSTN gateway through the first metropolitan ATM network wherein the PSTN gateway is operational to interwork the second ATM PVC with a connection to a local telephone network; and

a third ATM PVC from the first business hub to the PSTN gateway through the first metropolitan ATM network wherein the PSTN gateway is operational to interwork the third ATM PVC with a connection to a long distance telephone network.

2. The communications network of claim 1 wherein the communications network includes the local telephone network.

3. The communications network of claim 1 wherein the communications network includes the long distance telephone network.

4. The communications network of claim 1 further comprising:

a core ATM network that is connected to the first metropolitan ATM network; and

a fourth ATM PVC from the first business hub to a data network through the first metropolitan ATM network and the core ATM network.

5. The communications network of claim 4 wherein the data network is an Internet.

6. The communications network of claim 5 wherein the communications network further comprises an Internet Service Provider (ISP) and the fourth ATM PVC is from the first business hub to the ISP and wherein the ISP is operational to interwork the fourth ATM PVC with the Internet.

7. The communications network of claim 4 wherein the data network is a frame relay network.

8. The communications network of claim 7 wherein the communications network further comprises the frame relay network and the fourth ATM PVC is from the first business hub to the frame relay network and wherein the frame relay network is operational to interwork the fourth ATM PVC with a frame relay connection.

9. The communications network of claim 4 wherein the communications network includes the data network.

10. The communications network of claim 1 further comprising:

a core ATM network that is connected to the first metropolitan ATM network;

a second metropolitan ATM network that is connected to the core ATM network;

a third business hub that is connected to the second metropolitan ATM network; and

a fourth ATM PVC from the first business hub to the third business hub through the first metropolitan ATM network, the core ATM network, and the second metropolitan ATM network.

11. The communications network of claim 10 wherein the communications network further comprises:

the long distance telephone network;

a second PSTN gateway that is connected to the second metropolitan ATM network; and

a fifth ATM PVC from the third business hub to the second PSTN gateway through the second metropolitan ATM network, wherein the second PSTN gateway is operational to interwork the fifth ATM PVC with a connection to the long distance telephone network, and wherein the communications network is operational to connect a call through the first business hub, the third ATM PVC, the long distance network, the fifth ATM PVC, and the third business hub.

12. The communications network of claim 1 wherein the first business hub is operational to interwork between ATM and a plurality of different formats.

13. The communications network of claim 12 wherein the first business hub has an ethernet interface and an ATM interface.

14. The communications network of claim 12 wherein the first business hub has an fiber distributed data interface and an ATM interface.

15. The communications network of claim 12 wherein the first business hub has a V.35 interface and an ATM interface.

16. The communications network of claim 12 wherein the first business hub has an RS-422 interface and an ATM interface.

17. The communications network of claim 12 wherein the first business hub has a high speed serial interface and an ATM interface.

18. The communications network of claim 12 wherein the first business hub has a DS3 interface and an ATM interface.

19. The communications network of claim 12 wherein the first business hub has an T1 interface and an ATM interface.

20. The communications network of claim 12 wherein the first business hub has an Internet Protocol interface and an ATM interface.

21. The communications network of claim 12 wherein the first business hub has a frame relay interface and an ATM interface.

22. The communications network of claim 12 wherein the first business hub has an OC-3 to interface and an ATM interface.

23. The communications network of claim 12 wherein the first business hub has an OC-12 interface and an ATM interface.

24. The communications network of claim 1 wherein the communications network includes a service node that is connected to the first metropolitan ATM network and that includes an ATM switch.

25. The communications network of claim 1 wherein the communications network includes a service node that is connected to the first metropolitan ATM network and that includes a router.

26. The communications network of claim 1 wherein the communications network includes a service node that is connected to the first metropolitan ATM network and that includes the PSTN gateway.

27. The communications network of claim 1 wherein the communications network includes a service node that is connected to the first metropolitan ATM network and that includes a web server.

28. The communications network of claim 27 wherein the web server is operational to provide a customer with service subscription information.

29. The communications network of claim 27 wherein the web server is operational to provide a customer with a graphical depiction of at least portions of the communications network that provide service to the customer.

30. The communications network of claim 27 wherein the web server is operational to provide a customer with communications network performance information.

31. The communications network of claim 27 wherein the web server is operational to provide a customer with communications network status information.

32. The communications network of claim 1 further comprising:

an ATM access multiplexer that is connected to the first metropolitan ATM network;

a Digital Subscriber Line (DSL) multiplexer that is connected to the ATM access multiplexer; and

a third business hub that is connected to the DSL multiplexer by a DSL/ATM connection.

33. The communications network of claim 32 wherein the ATM access multiplexer and the DSL multiplexer are located in a central office.

34. A method for deploying a communications network that comprises:

(a) deploying a first network architecture that is comprised of a plurality of first business hubs that are each connected to a metropolitan ATM network that is connected to a core ATM network and that are each operational to interwork between ATM and a plurality of different formats and, wherein each first business hub has a first ATM Permanent Virtual Connection (PVC) that is connected through the metropolitan ATM network to a Public Switched Telephone Network (PSTN) gateway that interworks the first ATM PVC with a connection to a local telephone network, wherein each first business hub has a second ATM PVC that is connected through the metropolitan ATM network to the PSTN gateway that interworks the second ATM PVC with a connection to a long distance telephone network, wherein each first business hub has a third ATM PVC that is connected through the metropolitan ATM network and the core ATM network to a data network;

(b) deploying a second network architecture by adding an ATM access multiplexer that is connected to the metropolitan ATM network, by adding a Digital Subscriber Line (DSL) multiplexer that is connected to the ATM access multiplexer, and by adding a plurality of second business hubs that are each connected to the DSL multiplexer and that are each operational to interwork between ATM and a plurality of different formats;

(c) deploying a third network architecture by adding a plurality of work-at-home hubs that are each connected to the DSL multiplexer and that are each operational to interwork between ATM and a plurality of different formats, by adding a session manager that is connected to the metropolitan ATM network, and by adding provider agents to the PSTN gateway and to the work-at-home hubs wherein the provider agents and the session manager are operational to establish Switched Virtual Circuits (SVCs) that interconnect the work-at-home hubs and the PSTN gateway; and

(d) deploying a fourth network architecture by adding a plurality of residential hubs that are each connected to the DSL multiplexer and that are each operational to interwork between ATM and a plurality of different formats, and by adding a plurality of analog hubs that are each connected to the metropolitan ATM network and that are each operational to interwork between ATM and conventional telephony connections, and wherein the provider agents are added to each of the residential hubs and the analog hubs.

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